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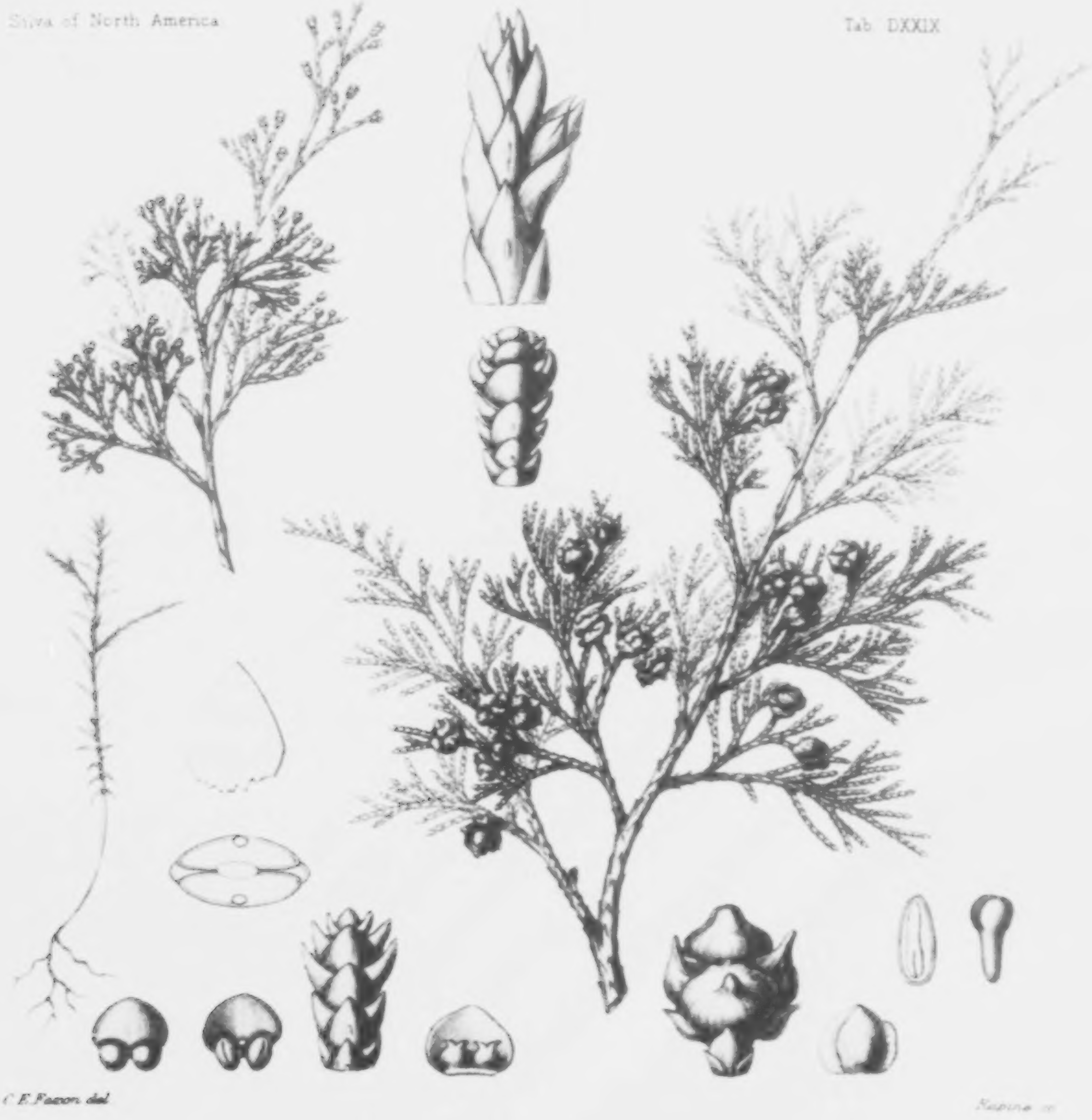
THE ECOLOGY OF ATLANTIC WHITE CEDAR WETLANDS: A COMMUNITY PROFILE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THE ECOLOGY OF ATLANTIC WHITE CEDAR WETLANDS:
A COMMUNITY PROFILE

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PREFACE

This monograph on the ecology of Atlantic white cedar wetlands is one of a series of U.S. Fish and Wildlife Service profiles of important freshwater wetland ecosystems of the United States. The purpose of the profile is to describe the extent, components, functioning, history, and treatment of these wetlands. It is intended to provide a useful reference to relevant scientific information and a synthesis of the available literature.

The world range of Atlantic white cedar (*Chamaecyparis thyoides*) is limited to a ribbon of freshwater wetlands within 200 km of the Atlantic and Gulf coasts of the United States, extending from mid-Maine to mid-Florida and Mississippi. Often in inaccessible sites and difficult to traverse, cedar wetlands contain distinctive suites of plant species. Highly valued as commercial timber since the early days of European colonization of the continent, the cedar and its habitat are rapidly disappearing.

This profile describes the Atlantic white cedar and the bogs and swamps it dominates or co-dominates throughout its range, discussing interrelationships with other habitats, putative origins and migration patterns, substrate biogeochemistry, associated plant and animal species (with attention to those that are rare, endangered, or threatened regionally or nationally), and impacts of both natural and anthropogenic disturbance. Research needs for each area are outlined. Chapters are devoted to the practices and problems of harvest and management, and to an examination of a large preserve recently acquired by the USFWS, the Alligator River National Wildlife Refuge in North Carolina.

CONVERSION FACTORS

Metric to U.S. Customary

Multiply	*By*	*To Obtain*
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

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Many colleagues have generously shared their knowledge and data with me. Their contributions are recognized at pertinent points in the text as personal communications; Appendix D identifies each contributor and the primary geographic region or scientific field addressed.

I also wish to thank all contributors to the data base that became the first Flora Checklist (Laderman and Ward 1987), as noted in Appendix A, and the participants in the first Atlantic White Cedar Wetlands Symposium (Laderman 1987) which formed the basis for much of this profile.

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- CHAPTER 1 -

INTRODUCTION

1.1 GENERAL FEATURES

Atlantic white cedar *(Chamaecyparis thyoides)* is geographically restricted to freshwater wetlands in a narrow band along the eastern coastal United States ranging from Maine to Mississippi (Figure 1). Cedar-dominated wetlands are most commonly called cedar swamps or cedar bogs, with a variety of other designations restricted to specific regions (e.g., "spungs" in the Pine Barrens [Moonsammy et al. 1987]; "juniper lights" in the Great Dismal [Kearney 1901]; "juniper bogs" throughout the south).

Distinctive biotic assemblages dominated by Atlantic white cedar grow under conditions too extreme for the majority of temperate-dwelling organisms. The shallow, dark, generally acid waters are low in nutrients and are buffered by complex organic acids (e.g., humates, fulvic acids). Surficial deposits beneath cedar forests provide groundwater storage and discharge and recharge areas. Peats adsorb and absorb nutrients and pollutants (Gorham 1987), purifying and protecting ground and surface water with which they are in contact. In many regions, cedar wetlands are refugia for species that are rare, endangered, or threatened locally or nationally. The swamps form southern pockets for northern species at the geographic limits of their ranges, and similar northern pockets for southern species (Taylor 1915; New Jersey Pinelands Commission [NJPC] 1980), but many locally common aquatic plants and animals are absent from cedar swamps.

Many species successful in these extreme environments have evolved unusual strategies for survival. The modest sum of research at the microscopic level in Atlantic white cedar wetlands reveals many symbiotic relationships of varying degree, exotic pigment combinations, and a range of metabolic, morphological, and temporal adaptations (Laderman 1980, 1987). However, the difficulty of gaining entry into cedar swamps, their limited geographic distribution, and a general lack of awareness

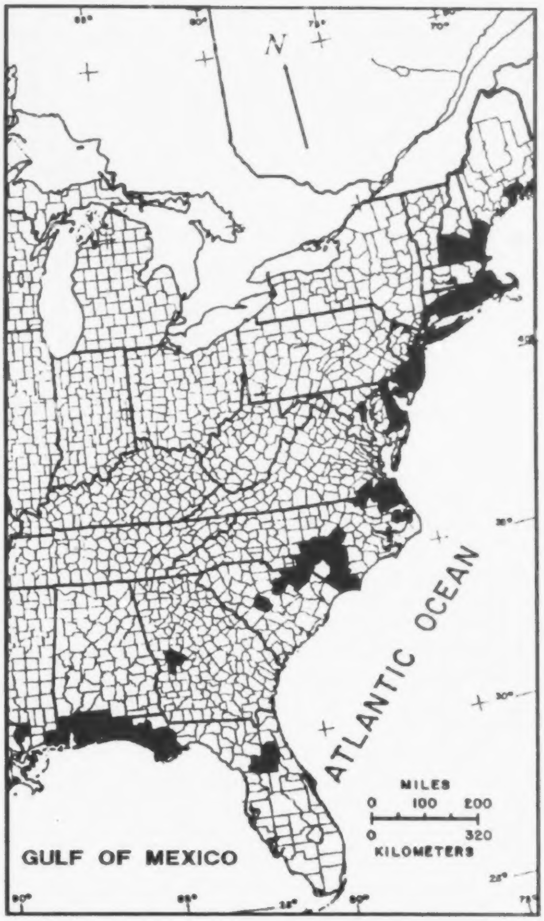

Figure 1. Distribution of *Chamaecyparis thyoides*. Records were compiled from field observations, herbarium records, published sources, and personal communications. Counties in which Atlantic white cedar has been found are inked in black (from Laderman 1982).

of the existence of the forests and their contents have discouraged extensive investigation of this wealth of intriguing life strategies.

European colonization and subsequent centuries of development have progressively so altered the landscape that much of the tree's original habitat was destroyed. Those stands that remain were in many cases protected only by the difficulty and high cost of penetrating the swamps. Cedar wetlands are increasingly encroached upon. They have been logged for their valuable lumber since the first explorers set foot in the New World (Emerson 1981; Frost, unpubl.; Kalm 1753-1761) and have been drained for agriculture for more than two centuries (Frost 1987; Sipple 1971-1972). As areas become more heavily populated, industrial, commercial, and residential uses displace cedar wetlands where they are not protected by law (Laderman et al. 1987; Roman et al. 1987). Cedar peat is being experimentally mined as an energy source.

Despite these multiple incursions, it is clear from the vigor of many stands that, with appropriate protection and, in some cases, aggressive management, cedars can successfully regenerate, and can repopulate many former cedar sites as well.

1.2 CLASSIFICATION

Atlantic white cedar occurs almost exclusively with other hydrophytes on hydric soils in wetlands commonly known as swamps and bogs. It is also found, though rarely, near established cedar stands as a colonizer where there are hydrophytes but nonhydric soils. This may occur, for instance, at the margins of new impoundments or excavations where hydric soils have not yet developed. Atlantic white cedar forests may be composed exclusively of an even-aged monospecific stand of close-ranked trees, which is often referred to in the literature as "typical" for *C. thyoides*. In forests successfully managed for harvest and regeneration, as well as in many natural stands that originated after fire or flood, this is often the picture. However, in many natural or selectively harvested situations, cedars grow in uneven-aged mixed stands which provide a greater diversity of habitats that support a more species-rich fauna and flora. Animal and plant life, and the variety of cedar landscapes they inhabit, are described in Chapters 2, 5, and 7; the known flora and fauna are recorded in Appendixes A and B respectively.

Under the U.S. Fish and Wildlife Service (USFWS) classification system (Cowardin et al. 1979) (Figures 2, 3), most cedar wetlands key out as:

SYSTEM Palustrine

CLASS Forested Wetland

SUBCLASS Needle-leaved Evergreen

DOMINANCE TYPE *Chamaecyparis thyoides*; in mixed forests, common associates in the canopy are red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), sweet bay (*Magnolia virginiana*), and one or more pine species: loblolly (*Pinus taeda*), white (*P. strobus*), or pitch pine (*P. rigida*)

WATER REGIME Nontidal; Semipermanently or Seasonally Flooded, or Saturated

WATER CHEMISTRY Fresh-Acid; rarely, Circumneutral

SOIL Organic; rarely, Mineral

A detailed classification of various cedar wetlands is presented elsewhere (Laderman, unpubl.).

Cedar swamps are situated shoreward of lakes, river or stream channels, or estuaries; on river floodplains; in isolated catchments; or on slopes. They may also occur (rarely) on bars or islands in lakes or rivers. Slightly elevated hummocks dominated by cedar are often interspersed with water-filled hollows in a repeating pattern that forms a readily identified functionally interrelated landscape.

1.3 RELATIONSHIP WITH ADJACENT HABITATS

The USFWS (Cowardin et al. 1979) designates the upland limits of wetlands as (1) the boundary between land with predominantly hydrophyte cover and land with predominantly mesophytic or xerophytic cover or (2) the boundary between predominantly hydric and nonhydric soil. The lower bounds of wetlands, both riverine and palustrine, lie at 2 m below low water or, if rooted plants grow beyond this depth, the border is at the deepwater edge of tree, shrub, or herbaceous emergent growth.

In practice, however, consideration of the ecosystem for management must go beyond technically defined borders. Indeed, the adjacent area may be a critical determinant in the structure and function of the entire wetland. The hydrological regime of a cedar wetland is a major determinant of the biota in both lotic (flowing) and lentic (nonflowing) systems. Mature Atlantic white cedars are adapted to a wide range of water depths, but rapid, prolonged change in water depth kills seedlings outright and stresses or kills mature specimens (see Figure 4)(Little 1950; Laderman 1980). In streamside, lakeside, and estuarine-border cedar swamps, the depth of water adjacent to and contiguous with a wetland is a major controlling influence on the wetland's water regime (Laderman, unpubl.). The impact of cedar wetlands on adjacent biota, hydrology, climate, etc., is at this time a matter of interest, but there are insufficient data for a clear understanding of such effects.

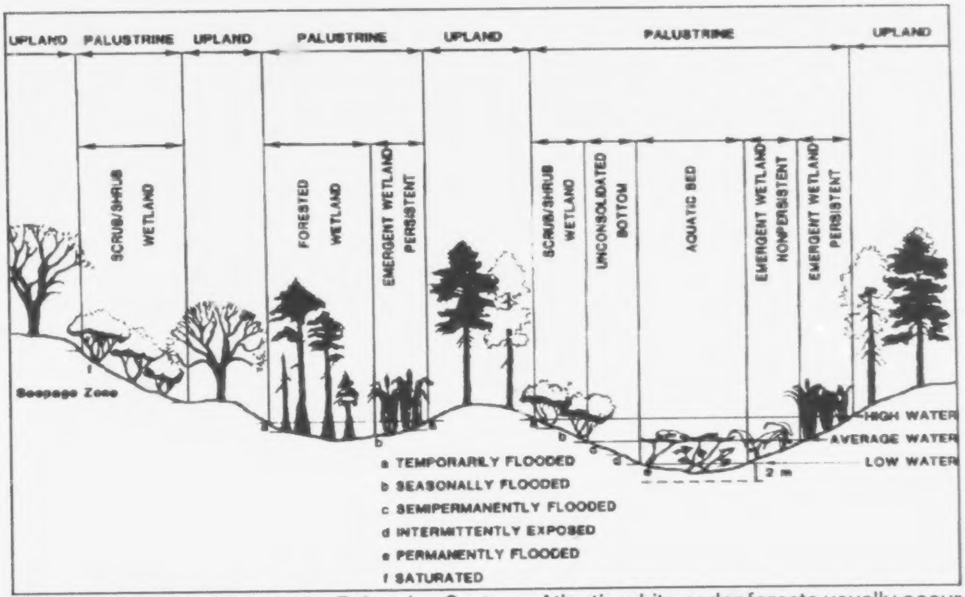

Figure 2. Cedar habitats in the Palustrine System. Atlantic white cedar forests usually occur in saturated (f) or temporarily flooded (a) zones on hummocks in freshwater wetland, in and below upland seepages, and in wet upland slopes adjacent to existing stands. Isolated, sometimes stunted cedars also emerge above a few saturated scrub-shrub or herbaceous savannah-like Palustrine situations (adapted from Cowardin et al. 1979).

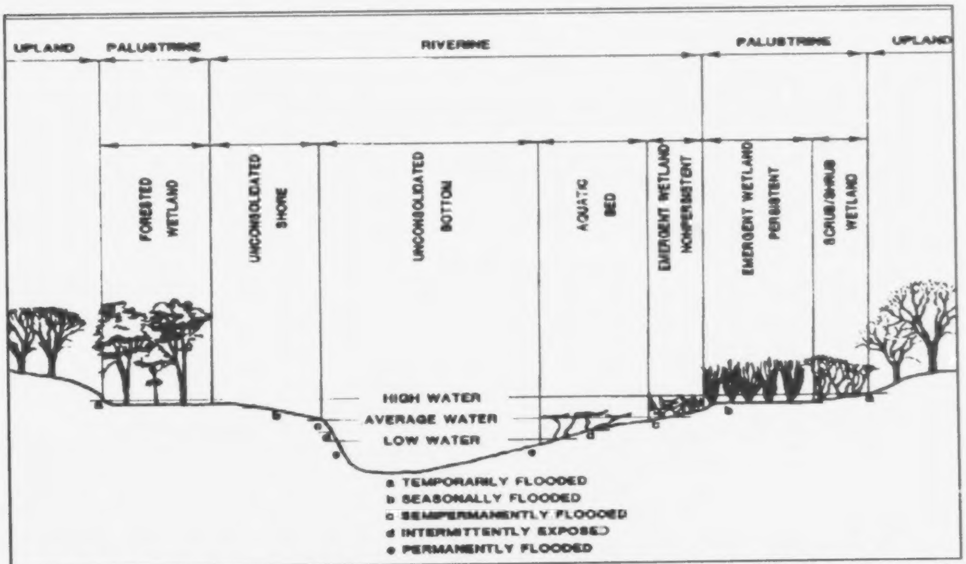

Figure 3. Cedar habitats in the Riverine System. Atlantic white cedar forests most frequently occur as streamside swamps or backswamp wetlands in areas not subject to extensive or frequent scouring. Cedars also colonize wet upland slopes adjacent to existing stands; isolated, sometimes stunted cedars also emerge above a few saturated scrub-shrub or herbaceous savannah-like situations adjacent to streams (adapted from Cowardin et al. 1979).

1.4 ORIGINS AND MIGRATION OF CEDAR FORESTS

1.4.1 Glacial Effects

The advance and wasting of glaciers strongly influenced the topography of the land both under the glaciers and over the entire continent's coastal area, due to direct glacial action, isostatic crustal movement, and major variations in sea level. During earlier interglacial periods, the northeast coast of the United States has been as far as 72 km further inland than today's shore; during the Wisconsin glaciation, sea level was as much as 60 to 80 m lower than its current height (Bloom 1983). The extent and timing of sea level rise and fall remains controversial (Bloom 1983).

Glacial melting from 17,000 to 10,000 years before the present (B.P.) led to the formation of glacial lakes and outwash beds of various sizes. Glacial lakebeds, kettleholes of the glacial moraine, and outwash plain streambeds are landscape features that now support cedar communities in the Northeast (Figure 5). Further south, glacial meltwaters filled rivers and streams, the remnants of which now form the stream bank and backswamp wetlands (Figure 6) in the New Jersey Pine Barrens, the Delmarva peninsula, Florida, and elsewhere. Such environments provide habitats for cedar growth. Conditions peculiar to the mid-Atlantic region are discussed in the Dare County case study (Chapter 7).

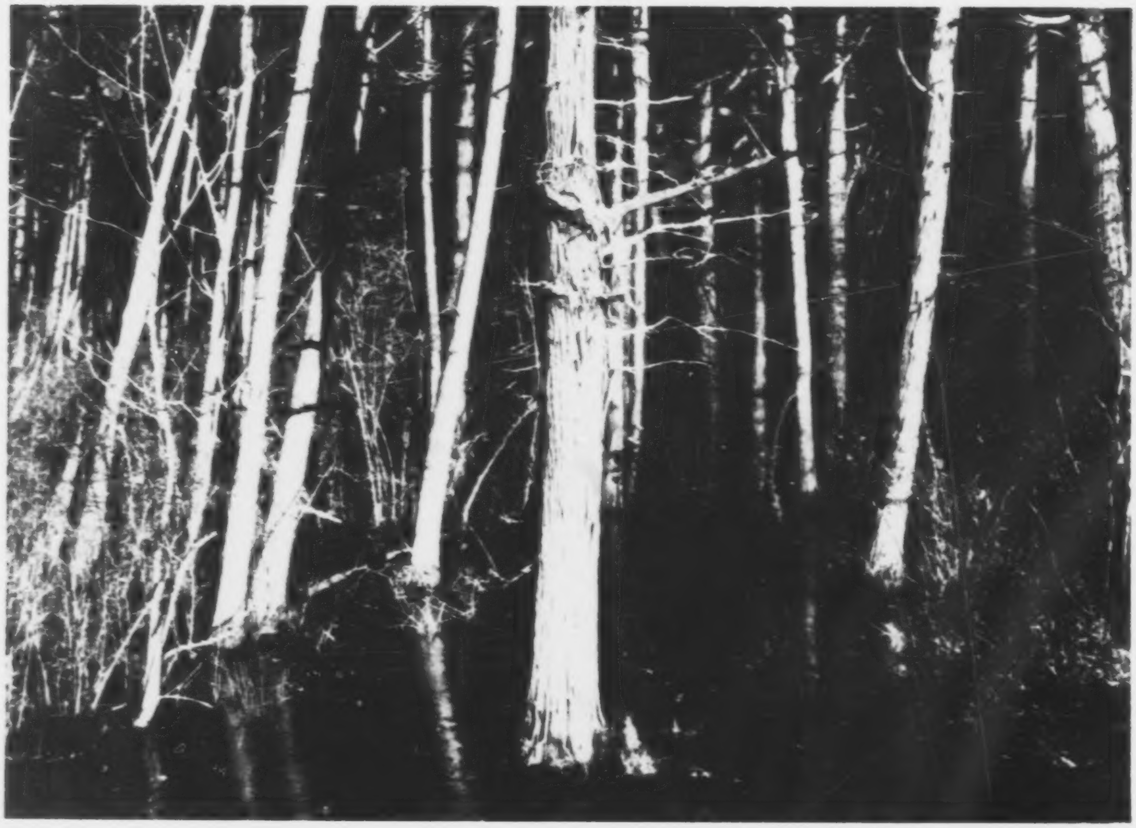

Figure 4. Cumloden Swamp, Falmouth, Massachusetts. Permanent high water, the result of damming by a roadway, is causing the slow death of mature cedars. This picture was taken five years after the road was built, and one year before the death of the last cedars.

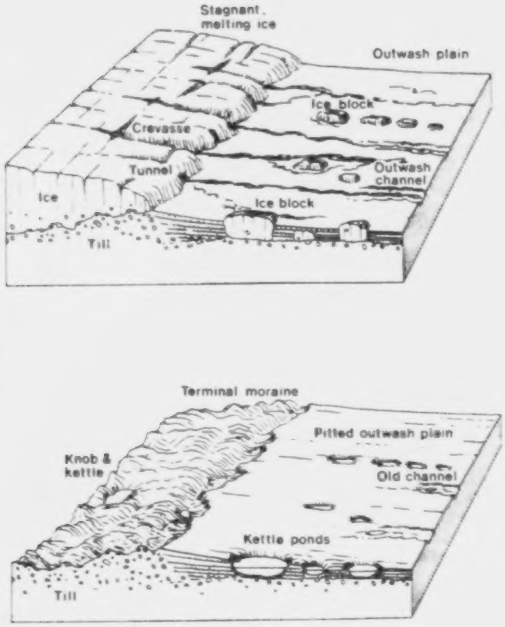

Figure 5. Origins of glacial kettle and outwash wetlands. Conditions close to the margin of an almost stagnant ice sheet are shown diagrammatically in the upper block diagram. The lower diagram shows the same area after the ice is entirely gone. Cedar forests develop in kettles and along outwash channels (adapted from Strahler 1966).

1.4.2 Establishment and Survival

Since the beginning of the current interglacial period, the long-term overall rise in sea level, averaging about one mm per year due to glacial melting and land subsidence, has played an important role in the development of many cedar wetlands. A. Redfield, (1965) in the context of a rising sea level, proposed a model for the development of coastal salt marshes, which he extended to the development of coastal freshwater swamps (A. Redfield, pers. comm.). Redfield noted that near the seacoast, the rising sea level more or less keeps pace with peat accumulation lifting the lens of freshwater above it. The effect of the rise in ground-water levels is that existing wetlands remain wet, promoting the continuous presence of some cedar swamps for as much as 6,800 years (Belling 1977).

Along the coast, seawater inundated freshwater wetlands, giving rise to the accumulation of layers of saltmarsh peat superimposed on freshwater peat. Ample macrofossil evidence of the killing of cedar forests by saline incursion is found all along the Atlantic seaboard (Figure 7). Atlantic white cedar trunks, sometimes in the same position as in life or as they fell hundreds of years earlier, may be seen at low tides below saltmarsh turf on the coasts of New Hampshire, Massachusetts, New Jersey, Virginia, and elsewhere (Bartlett 1909; Heusser 1949, 1963; Belling 1977), and buried deep in off-shore marine sediments (Redfield and Rubin 1962).

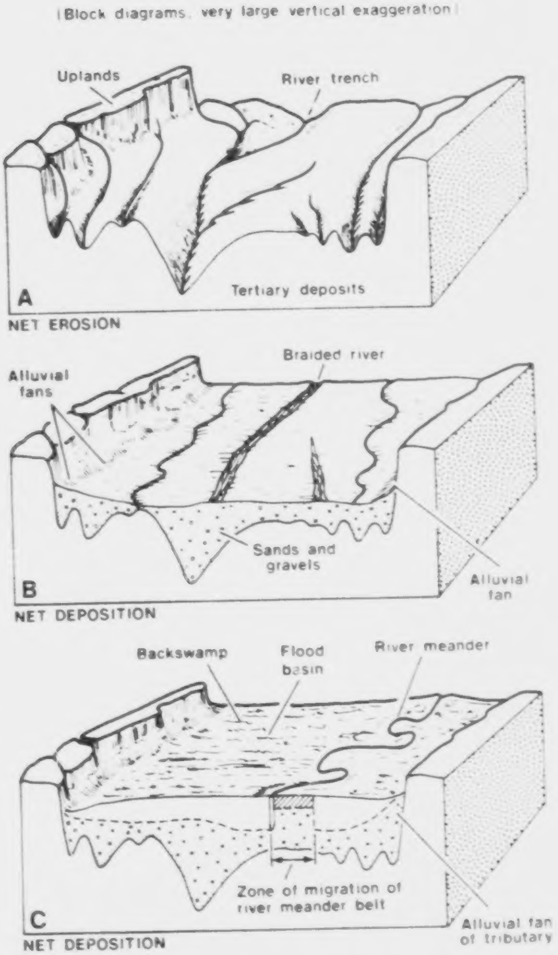

Figure 6. Origins of backswamp cedar wetlands. (a) When sea level was below the present position, the river trenched its valley. (b) As sea level rose, glacial meltwater poured down the river, creating a braided stream choked with sand and gravel. (c) Deposits of today's meandering river, established at a yet higher sea-level position, have buried the older braided stream deposits. Cedar wetlands develop in backswamps and along small streambanks (adapted from Long 1974).

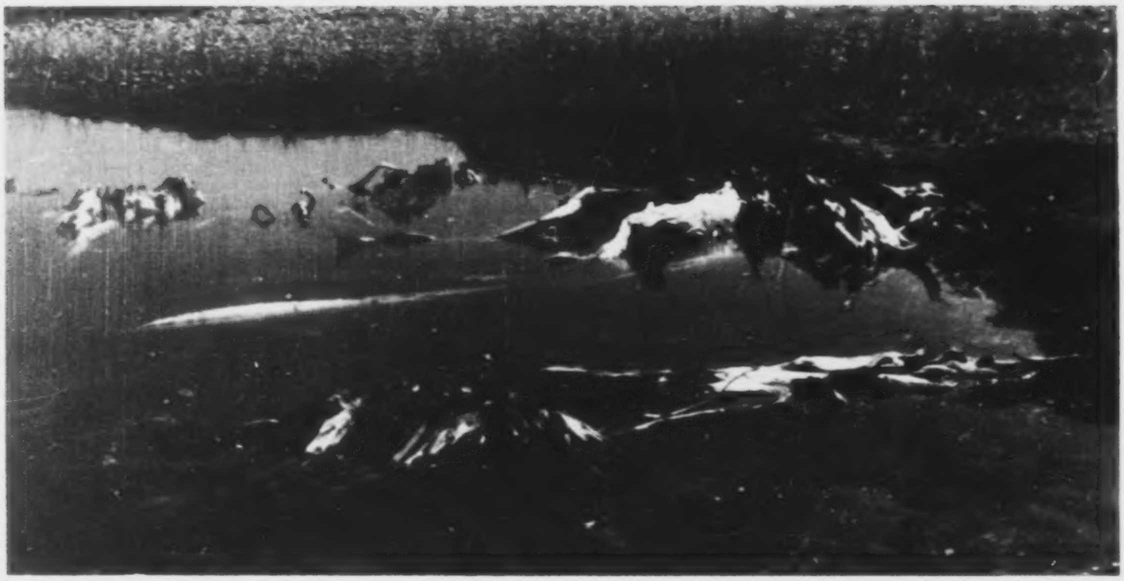

Figure 7. Atlantic white cedar logs in exposed freshwater peat underlying a salt marsh on Buzzard's Bay, Massachusetts. Note that many trunks and roots remain as they grew in the forest floor. Photo by I. Laderman.

1.4.3 Time and Path of Migration

Atlantic white cedar appears to have moved southward to refugia on the Gulf Coastal Plain during full glaciation (Belling 1977; Delcourt and Delcourt 1977). It probably began its northward migration from the Gulf refugia during the late glacial period, between 17,000 and 10,000 years B.P. (Belling 1977 and unpubl.). Some evidence for this view is that cedar (Cupressaceae) pollen grains are found in North Carolina sediments that predate the most recent glaciation (25,000 yrs B.P.), but are absent during the glacial epoch (21,000 to 10,000 yrs B.P.). Cupressaceae pollen reappears there at 10,000 yrs B.P. (the beginning of the present interglacial period), and is continuously recorded in the peats until the present time (Whitehead 1981).

Dated macrofossils of Atlantic white cedar from as early as 9500 yrs B.P. (Watts 1979) and 7700 yrs B.P. (Psuty et al. 1983) were recorded from unglaciated sites (Table 1; Figure 8). Most palynologists do not distinguish between the pollen grains of *Thuja*, *Juniperus*, and *Chamaecyparis*, which are all in the family Cupressaceae and are very similar in pollen morphology (see Figures 2 and 3). Belling (1977 and unpubl.) uses macrofossil evidence in conjunction with pollen data to separate the three genera and outlines a probable sequence of cedar migration in the glaciated region. Arrival of the species at specific sites during postglacial time was determined by radiocarbon dating results for peats containing both macrofossil and pollen evidence. Belling (unpubl.) postulates that northward movement of Atlantic white cedar was influenced more by the distance from the nearest refugium (i.e., the seed source) and the availability of suitable growth sites than solely by warmer climate. The most suitable sites are those with a favorable water regimen (discussed in Section 3.2 [silvical habits] and Section 4.1 [hydrology]) and a consolidated peat substrate.

Basin depths range from 3 to 9 m in glacial sites; the build-up of peat is evidence of the rise in water tables throughout the region. Belling (1977 and unpubl.) noted that Atlantic white cedar was virtually continuous in all sampled glaciated sites from the time of its establishment to the present.

1.4.4 Sediment Stratigraphy

Peat contains an excellent record of events and biological succession. Sediment cores from cedar bogs in the glaciated region reveal a well-defined vertical stratigraphy (Figure 9). At most sites, the overlying organic layer consists, in descending sequence, of woody cedar peat, woody-fibrous or fibrous shrub peat, sedge peat, mossy peat (rarely), and finally gyttja formed from benthic and planktonic lake flora and fauna. The inorganic basal sediments are composed of sand and/or clay. Water layers may interrupt the sediments.

Table 1. Earliest records of Atlantic white cedar in the United States.

Years Ago	Location	Physiography	Source
Non-glaciated sites:			Whitehead 1981[a]
25,000 yr BP	NC		
10,000 yr BP	NC		
9500 yr BP	NJ	Coastal plain	Watts 1979[a]
7700 yr BP	NJ	Coastal plain	Psuty et al. 1983
Glaciated sites:			Belling 1977[b]
6800 yr BP	Westboro MA	Piedmont	
5400 yr BP	Pachaug RI	Piedmont	
4000 yr BP	Antrim NH	Appalachian	
3800 yr BP	Genessee RI	Piedmont	
3000 yr BP	Wellfleet MA	Coastal plain: moraine	
2300 yr BP	Sterling Forest NY	Appalachian	
2200 yr BP	Belleplain NJ	Coastal plain	
400 yr BP	Fairhill NH	Coastal plain	
≤300 yrs	High Point NJ	Appalachian	

[a] Pollens were identified as Cupressaceae; macrofossil and site evidence indicated *C. thyoides*.

[b] Pollens were identified as *Chamaecyparis*, corroborated by macrofossil and site evidence.

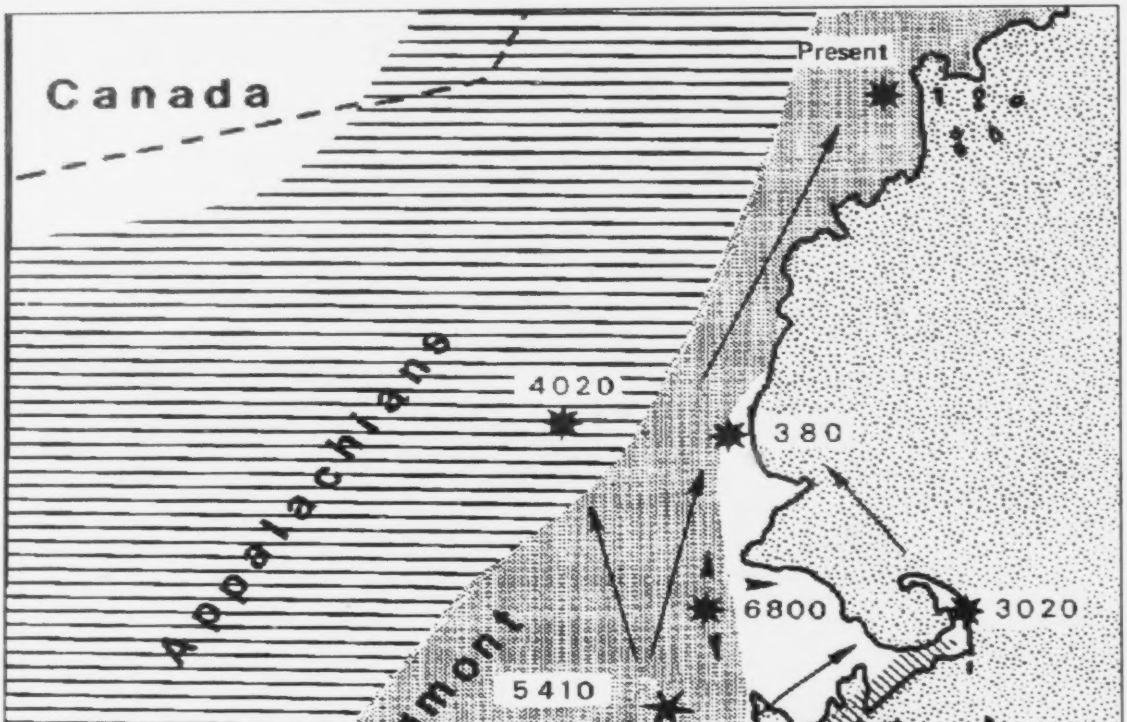

Figure 8. Possible migration routes of Atlantic white cedar in the northeastern United States. Stars denote peat core analysis sites. Numbers indicate the approximate time at which *C. thyoides* became established (years before present, estimated by radiocarbon [R.C.] dating); first appearance is in parentheses (from Belling 1977).

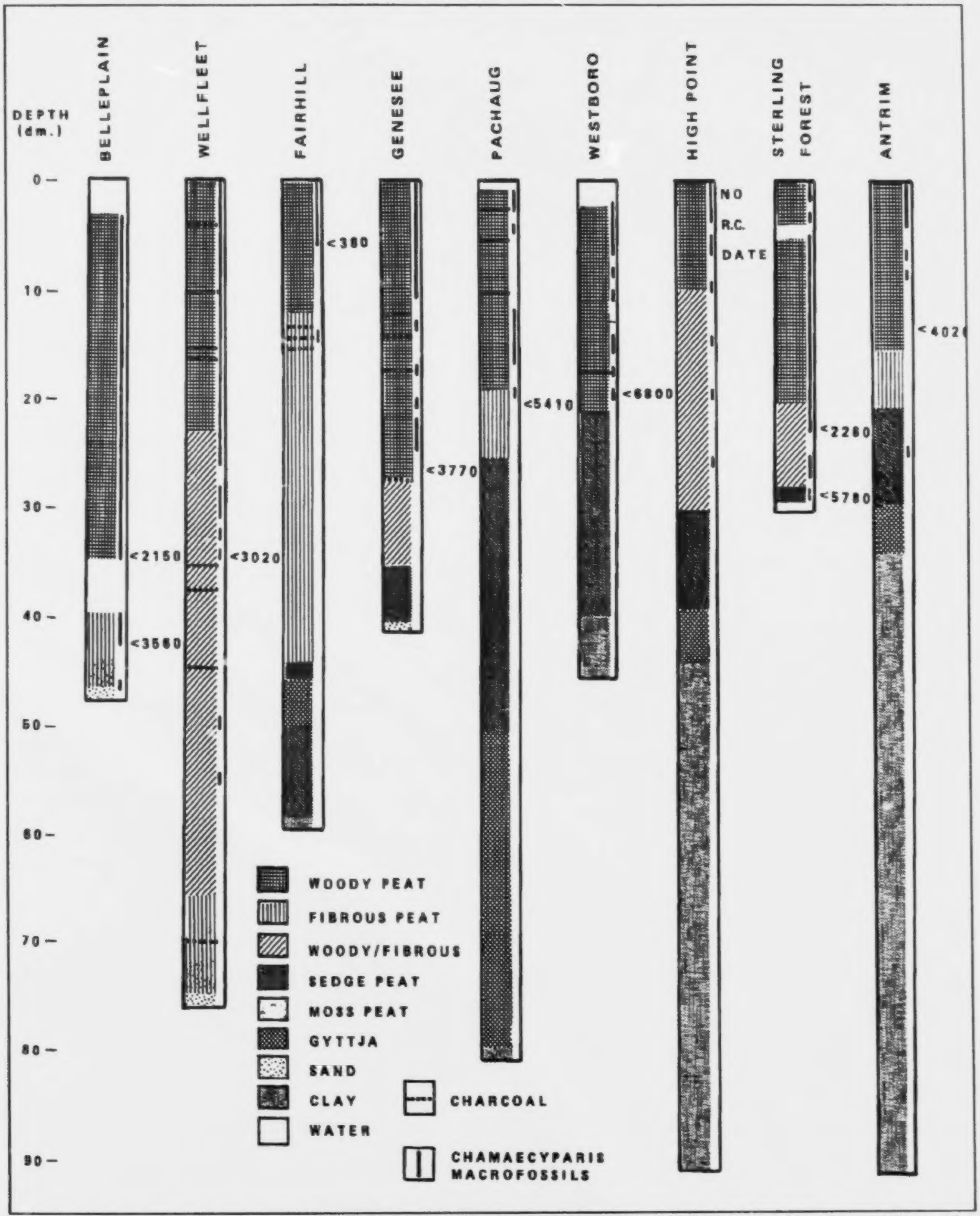

Figure 9. Macrofossil sediment stratigraphy in glaciated cedar wetlands indicating Atlantic white cedar migration patterns. Radiocarbon (R.C.) dates: see notes, Figure 8 (from Belling 1977, and unpubl.).

CHAPTER 2 -

REGIONAL OVERVIEW

2.1 INTRODUCTION

The aspect of an Atlantic white cedar wetland is so distinctive that the casual observer may think that all cedar swamps are similar in physical structure and community composition. This is far from the truth when the cedar is examined over its entire range from north to south, from sea level to mountain hollow, from acidic glacial kettle to boggy flatwood or seepage sandhill.

Cedar wetlands will be most clearly understood by examining what we know of each example. Therefore, some typical or unusual sites are described below, including those at the farthest extents of the cedar's range, the highest elevation cedar swamp (altitude: 457 m), a domed bog, swamps with a dense great laurel (*Rhododendron maximum*) understory, floating bog mats with dwarfed trees, a wetland in a deep fracture in bedrock, narrow stream-border Pinelands swamps, millponds, a Carolina bay, a sandhill seepage, and a sandy stream terrace.

2.2 GLACIATED NORTHEAST

Atlantic white cedar wetlands dot a 130 km-wide band along the coastal region of the Northeastern United States from the southern extent of glaciation (Figure 10) along New York's Long Island and New Jersey's Hackensack Meadows, north to mid-Maine at 44° north latitude (Figure 11). *Chamaecyparis thyoides* grows from sea level to 457m elevation, but the great majority of stands are found between sea level and 50 m. It is probable that the distribution of the species was always restricted to sites too wet for most other northeastern trees. There is standing water in many northern cedar swamps for half the growing season or longer (Laderman et al. 1987; Golet and Lowry 1987); the soil is primarily organic; and ground water is highly acidic (pH 3.1 - 5.5 [Laderman 1980; Golet and Lowry 1987]).

2.2.1 Climatology

The growing season of Atlantic white cedar in the glaciated northeast ranges from 139 days in Maine to 211 days in northern New Jersey. Summers are relatively cool and wet. Average maximum daily temperatures in July range between 13 and 16 °C. The extreme high temperatures, 39 to 41 °C, do not differ from those in the southernmost parts of the cedars' range, although the total degree- days and average temperatures differ markedly. The lowest temperatures in the glaciated cedar wetland area range from -40 °C in Maine to -22 °C in New Jersey. Average annual precipitation is between 101 and 119 cm (data from Ruffner and Bair 1981).

2.2.2 Distribution

Generally, *Chamaecyparis* decreases in abundance with increasing distance from the coast. Low tides and storms reveal cedar stumps buried under saltmarsh peat near the coast from Kittery Point, Maine to New Jersey, evidence of the slow rise of sea level in this region (Redfield and Rubin 1962). Atlantic white cedar was far more plentiful in each of these states a few hundred years ago, but there is no evidence that its range ever extended significantly to the west or north of its current extent.

In New England, Atlantic white cedar is most abundant in southeastern Massachusetts, Rhode Island, and eastern Connecticut (Golet and Lowry 1987; Sorrie and Woolsey 1987; Laderman, unpubl.). Its distribution (Figure 11) appears to be closely related to glacial features such as moraine hollows, glacial kettles, or old lake beds.

There are 11 known *Chamaecyparis* stands in Maine (Eastman, unpubl.; B. Vickery, pers. comm.) and about twice that number in New Hampshire (H. Baldwin, pers. comm.; F. Brackley, pers. comm.; P. Auger, pers. comm.). In Massachusetts, cedar swamps are found in all but three of the 64 towns in Bristol, Plymouth, and Barnstable (the State's three major southeast counties), and approximately 30

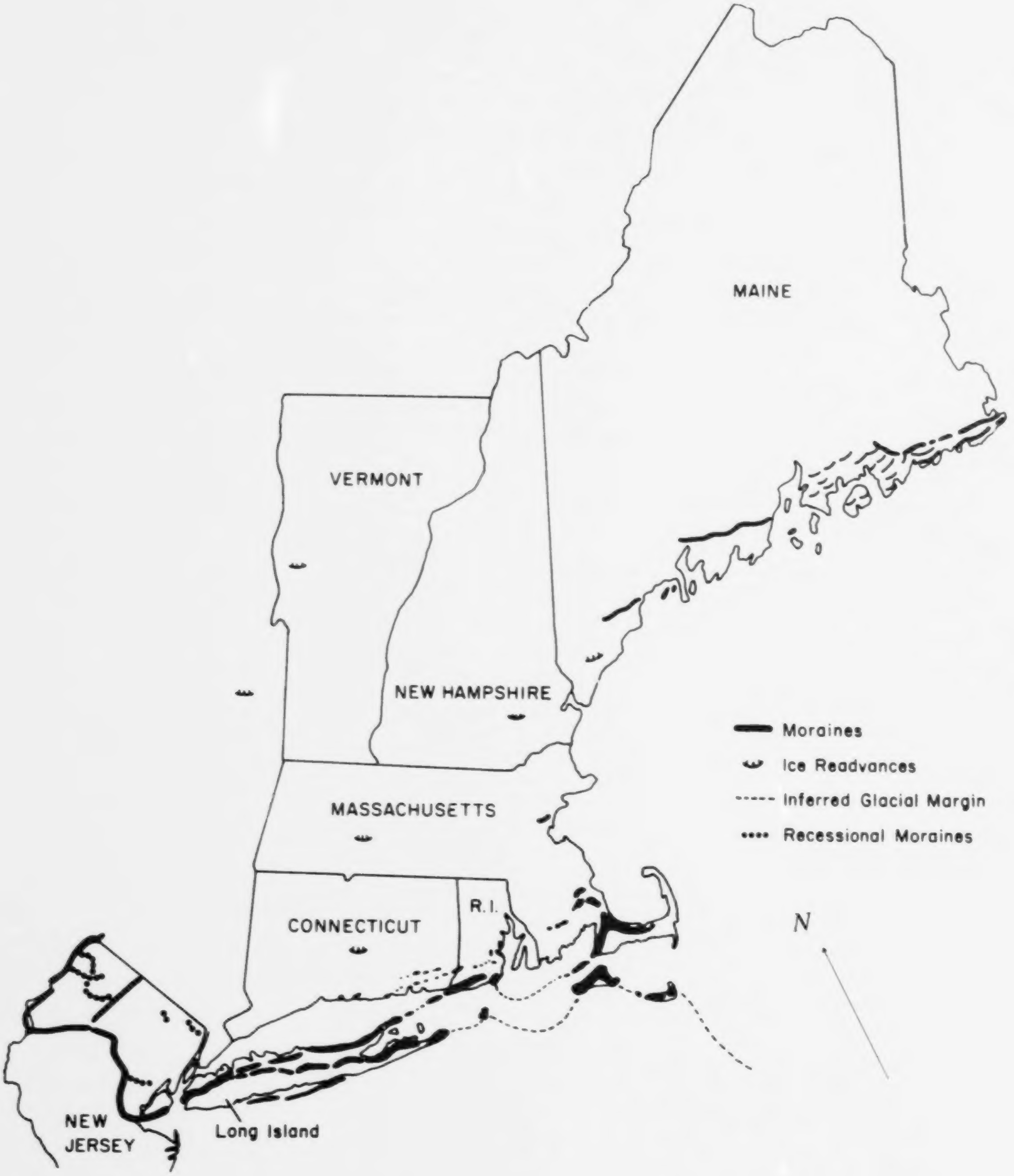

Figure 10. Distribution of glacial moraines and ice readvance localities in the northeastern United States (from Laderman et al. 1987, redrawn from Larson and Stone 1982).

stands are scattered north and west of Boston (Sorrie and Woolsey 1987). Rhode Island contains more than 130 stands in four of the State's five counties (D. Lowry, pers. comm.). There are records of 39 *C. thyoides* wetlands extant in Connecticut (K. Metzler, pers. comm.); a half century ago Noyes (1939) counted 86 stands, 72% of them in the two easternmost counties of New London and Windham. Two small cedar bogs are all that remain in mainland New York State (Lynn 1984), but many stands persist in southeastern Long Island (J. Turner, pers. comm.). While extensive cedar wetlands are found south of the limit of glaciation in the Pine Barrens of southern New Jersey, only seven are known from the glaciated part of the State (D. Snyder, pers. comm.). Early reports (e.g., John Bartram's 18th century letters [Darlington 1849]; Kalm's 1753-1761 diary [Benson 1966]) described rich cedar forests in the eastern tip of Pennsylvania at the New Jersey border, but *Chamaecyparis* has been extirpated in Pennsylvania for many years (Illick 1928).

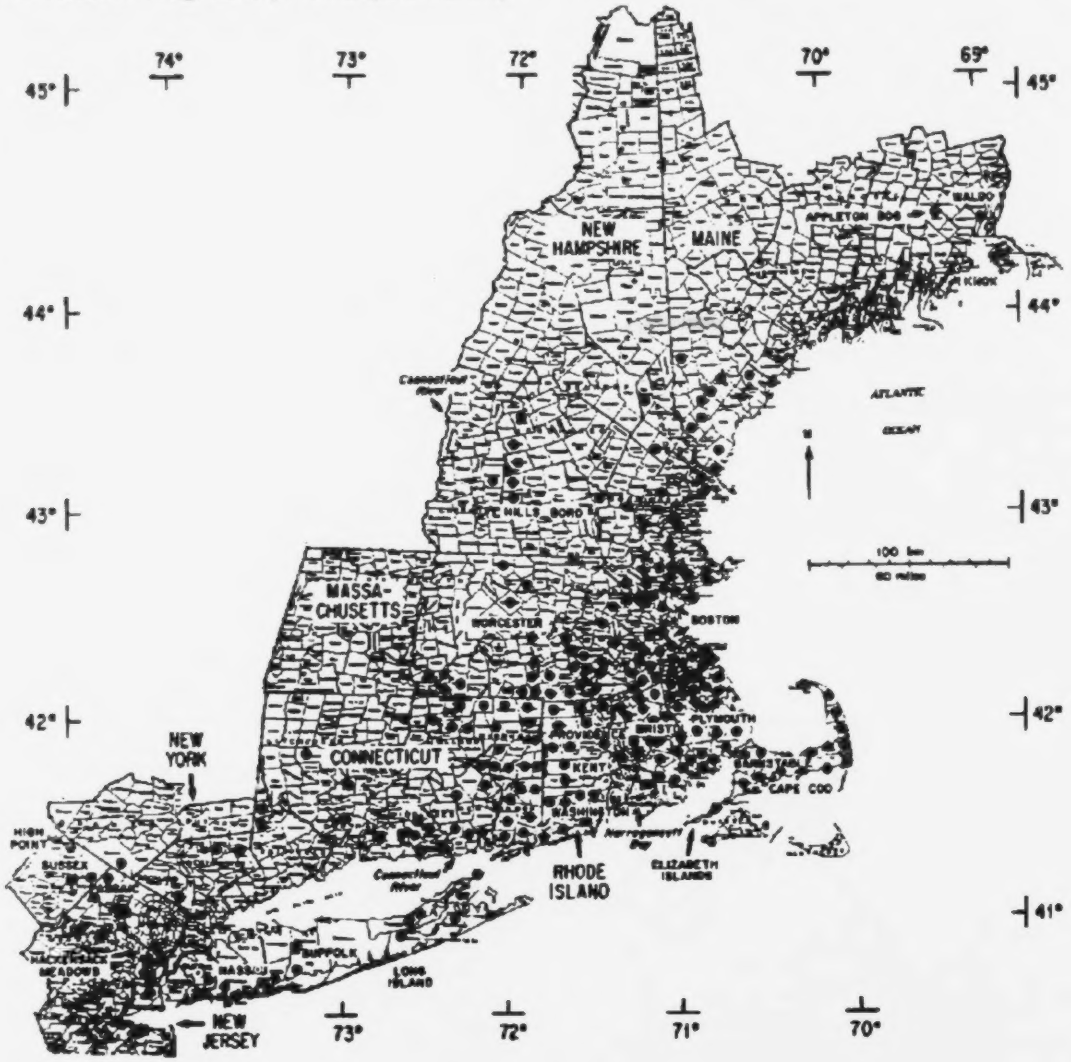

Figure 11. The historical distribution of *C. thyoides* in towns of the glaciated northeastern United States (from Laderman et al. 1987).

Throughout the glaciated Northeast, only a fraction of earlier stands remains. Information on the current status and location of many sites is available from the Natural Heritage Programs, the Nature Conservancy, and State natural diversity data bases.

The following descriptions of stands are adapted from Laderman et al. (1987).

Maine. The northern and eastern edges of the worldwide native range of *C. thyoides* are in the state of Maine (Rossbach 1936). Maine's eleven cedar stands are scattered from Knox County southward to the New Hampshire border, generally within 20 km, and never more than 48 km, from the Atlantic coast. They are found among low hills, between ridges, and along lakes and swampy valleys with meandering streams (Eastman 1977).

Appleton Bog, at 44° 20' north latitude the northernmost site of the tree's range, was discovered in 1931 by Rossbach (1936). The 92 ha site contains well-developed *Sphagnum*-carpeted hummock and hollow topography dominated by vigorously reproducing, healthy cedars (Worley 1976). Hummock tops lie above the water table most of the growing season; in droughts, the water table remains within a few centimeters of the surface of the hollows. There are no streamcourses within the cedar-dominated area, and there is neither inflow nor outflow of surface water. Sixteen hectares last logged in the 1950's are vigorously regenerating. The cedars form dense, pure stands, averaging 15 to 40 cm in diameter at breast height (dbh); the maximum height seen was ca. 18 m (Worley 1976). *Potamogeton confervoides*, a pondweed rare in Maine, grew in a pond within the bog a decade ago but may have been recently extirpated as it has not been found in more recent explorations (G. Rossbach, unpubl. letter).

Northport, in Waldo County, at 69° 01' west longitude is the easternmost location known for *C. thyoides;* it contains a strikingly different cedar site just a few km southeast of Appleton Bog. In 1930, Rossbach (1936) discovered stunted cedars scattered and clumped on a 0.5 km-wide bog mat floating at one end of Knight's Pond. It has apparently changed little in this half century. Mature cedars (some only 15 cm tall) share the tufted mat surface with stunted white pine (*Pinus strobus*), black spruce (*Picea mariana*), tamarack (*Larix laricina*), and a rich variety of ericaceous shrubs, carnivorous herbs, and *Sphagnum* mosses (B. Vickery and A. Laderman, unpubl. field notes).

Saco Heath, northwest of Saco, York County, is the only domed bog known to contain *Chamaecyparis thyoides*, and is possibly the southernmost raised coalesced peatland in the eastern United States. Saco is the only large *Sphagnum* bog in southern Maine, and is one of the southernmost Atlantic coast breeding sites known for the palm warbler (*Dendroica palmarum*) (H. Tyler and M. Michener, pers. comm.).

The earliest reports of *C. thyoides* in Maine (Goodale 1861) indicated that it grew in York and Kittery at the southernmost tip of Maine's seacoast, where now only gnarled stumps of a drowned cedar forest are sometimes visible at extreme low tide.

New Hampshire. More than twenty Atlantic white cedar stands are scattered through five of New Hampshire's ten counties (P. Auger, pers. comm.; H. Baldwin, pers. comm.). A few rare high-altitude *Chamaecyparis* swamps are found here. Robb Reservoir in Stoddard at 388 m is second in elevation only to High Point, New Jersey. At least seven stands are found above 250 m, six of them growing in Hillsborough County (Svenson 1929; Baldwin 1961, 1963, 1965, and pers. comm.; F. Brackley, pers. comm.). Little has been published about the state's cedar wetlands; their continual loss is documented repeatedly in Baldwin's short notes (1961, 1963, 1965) and unpublished letters, and in unpublished records of the New England Nature Conservancy and the Society for the Protection of New Hampshire's Forests.

Massachusetts. In Massachusetts, Atlantic white cedar is commonest south of Boston, particularly in Plymouth and Bristol counties. Many acres of cedar swamp still exist here, although they are being encroached upon by urbanization. Cranberry bogs were often created from cedar wetlands, but it is difficult to determine how many acres historically supported Atlantic white cedar. Farther west, there are fewer wetlands and less optimal conditions for cedar growth. In some areas of western Massachusetts, in the Connecticut River valley and in northern Worcester County, cedars usually occur within black spruce and larch forests in a more boreal setting.

On Cape Cod, cedar bogs are sparsely distributed from Provincetown to the Cape Cod Canal, primarily in glacial kettles. Diaries of early explorers and colonists (Archer 1602 and Brereton 1602 [in Emerson 1981]; Emerson 1981) tell of many thick cedar stands on the Cape as well as on the adjacent Elizabeth Islands, where only a single cedar swamp remains today.

Despite the white cedar's historic abundance in Massachusetts, few studies of the state's cedar wetlands have been published. The Massachusetts Natural Heritage Program is currently preparing an inventory of the natural areas of the state and is gathering data hitherto unavailable. Even as the information is collected, large tracts are being threatened by major development.

Occurrences of cedar in the state may be grouped in three broad classes (1) pure forest stands with little other canopy vegetation (the most common cedar community of the mainland), (2) mixed stands, with cedar occurring among other wetland trees, primarily red maple, and (3) in kettles with an open body of water surrounded by a succession of zones in which cedar is one of the concentric rings of vegetation.

An example of the vegetation sequence surrounding a kettle pond would be: a band of emergent swamp loosestrife (*Decodon verticillatus*) rimmed by a *Sphagnum*-based mat, on which there is a succession of narrow shrub zones starting with perhaps some dwarf huckleberry (*Gaylussacia dumosa*), leatherleaf (*Chamaedaphne calyculata*), blueberry (*Vaccinium* spp.), and swamp azalea (*Rhododendron viscosum*), which sharply grade into Atlantic white cedar, and finally white pine, hemlock, and upland species. Some typical plants of the open *Sphagnum* zone would be pitcher plant (*Sarracenia purpurea*), sundew (*Drosera intermedia*), and occasional orchids such as rose pogonia (*Pogonia ophioglossoides*) or grass pink (*Calopogon pulchellus*).

A variation of this vegetation type is found on Cape Cod, where cedars may occupy relatively flat-surfaced kettles rimmed by a moat slightly deeper than the body of the wetland. The cedars, often the sole canopy tree, cluster on small hummocks that are spotted over the entire basin. The concentric vegetation pattern is condensed on each hummock, with ericaceous shrubs, sweet pepperbush (*Clethra alnifolia*), and ferns in tight array rising from a sphagnous carpet that continues into the water of the hollows.

Species otherwise rare in southern New England are found in *Chamaecyparis* wetlands, e.g., dwarf mistletoe (*Arceuthobium pusillum*), a tiny flowering parasite that causes deformation and death of at least the branches of the black spruce on which it grows; and heartleaf twayblade (*Listera cordata*), a northern species at its southern limit in Cape Cod (the only known extant location in the state). The northern parula warbler (*Parula americana*) in Massachusetts now breeds primarily in a few cedar wetlands, as the hanging lichen *Usnea*, its favored nesting material, is fast disappearing outside the cedar swamps.

Rhode Island. In Rhode Island, Atlantic white cedar is most abundant west of Narragansett Bay, particularly in Washington County and in the western sections of Kent and Providence Counties (D. Lowry and F. Golet, pers. comm.) There is very little cedar on the east side of the Bay, although place names such as "Cedar Swamp" suggest that the species was more common there in the past.

The largest stands of cedar occur within the state's three largest wetlands, all of which are situated on broad expanses of stratified drift less than 30 m above sea level. Cedar forest covers 240 ha of the 870-ha Chapman Swamp in Westerly. The remainder of this highly diverse wetland includes deciduous forest, shrub swamp, bog, marsh, and open water. Two-thirds of the 390-ha Indian Cedar Swamp in Charlestown supports cedar, but red maple (*Acer rubrum*) is the dominant species in most of the stands in which cedar occurs. In the Great Swamp, which occupies 1200 ha in South Kingstown, Richmond, and Charlestown, cedar covers some 90 ha; the great majority of this wetland consists of deciduous forest and shrub swamp.

Smaller stands of cedar are commonly found in glacial kettles (ice-block basins) which formed in stratified drift or in thick deposits of morainal material. A highly unusual stand of Atlantic white cedar occupies a kettle situated in outwash at the edge of Factory Pond, 9 m above sea level in South Kingstown. The trees in this 5-ha "forest" are 80 years old, but only 1-1.5 m tall. Bordered by the pond on one side, the stand is separated from the adjacent upland by a moat of open water and a quaking mat of low shrubs. The surface of this dwarf cedar bog is carpeted throughout with *Sphagnum* moss. The water table stays within a few centimeters of the surface all year, and the pH of the soil water drops as low as 3.1. The soil is a poorly decomposed, fibric peat. Growing in association with the cedars are leatherleaf, cranberries (*Vaccinium macrocarpon*, *V. oxycoccos*), cottongrass (*Eriophorum* sp.), and pitcher plant. At its deepest point, this kettle contains 9 m of peat.

Cedar wetlands along the Connecticut border in western Rhode Island generally lie at elevations ranging from 90 to 180 m. Most of these have developed over valley train deposits of stratified drift or in association with ice contact deposits. A very small percentage of these swamps lie directly on bedrock or on unstratified drift (more commonly known as glacial till). Most wetland basins in till or bedrock tend to be small, and peat deposits seldom exceed 2-3 m in thickness.

Red maple and black gum (*Nyssa sylvatica*) are the two tree species most commonly associated with Atlantic white cedar throughout Rhode Island, but eastern hemlock (*Tsuga canadensis*) is an important associate in many of the swamps lying above 90 m. In a small number of wetlands in northwestern Rhode Island, cedar grows in association with two boreal species, black spruce (*Picea mariana*) and larch (*Larix larina*) (R. Enser, pers. comm.).

Great laurel (*Rhododendron maximum*), a broad-leaved evergreen shrub which is common in upland areas of the southern Appalachians (Fernald 1950), is locally common as an understory species in both deciduous and evergreen wetland forests in southern Rhode Island and nearby Connecticut. This shrub grows to a height of 2.5 to 4.5 m and often forms such dense tangles that travel through the swamps is exceedingly difficult. As a result of the deep shade created by a dense canopy of cedar and a thick understory of great laurel, herbs are scarce to nonexistent in these swamps (Lowry 1984).

A striking example of the Atlantic white cedar-great laurel association can be seen in the Ell Pond-Long Pond Natural Areas Complex near the Connecticut line in Hopkinton. There a dense, 90-year old cedar forest containing hemlock as well as great laurel borders the northern and western shores of Ell Pond, which lies in a deep fracture in the local bedrock. The surrounding relief is rugged and bedrock outcrops are numerous. Between the forest and the water's edge is a narrow bog mat dominated by leatherleaf. Peat thickness ranges from 4 m in the forest interior to 8-9 m at the water's edge. The Ell Pond stand, which averages 13 m in height, is 98 m above sea level. Ell Pond and its associated wetlands represent Rhode Island's only National Natural Landmark. For further description of Rhode Island sites, see Lowry (1984) and Golet and Lowry (1987).

Connecticut. Thirty-nine cedar wetlands, all but six of them east of the Connecticut River, are known to contain living cedar in Connecticut at present (K. Metzler, pers. comm.). Some sites are reported to be in near-pristine condition, some are trampled and debris-strewn, and some are still being logged for cedar. A few are in public ownership, but most have no active conservation management.

Two cedar wetlands were designated as National Natural Landmarks in 1973: Chester Cedar Swamp, and Pachaug Great Meadow in Voluntown. A cedar log walkway and marked trail traverse a section of the Pachaug preserve containing over 200 ha of cedar in an approximately 350 ha swamp-bog-sedge meadow complex (K. Metzler, pers. comm.) drained by the Pachaug River. Pachaug and at least two other stands are known to contain sizable, vigorous, dense great laurel populations (Ledyard Cedar Swamp, and Bell Cedar Swamp in North Stonington) (K. Metzler, pers. comm.). Creeping snowberry (*Gaultheria hispidula*) is reputed to grow in one privately-owned swamp. North Windham Peat Bog contains a dense 30-ha white cedar swamp with black spruce, unusual in Connecticut. It is a combination not seen south of this point except in the montane Sterling Forest, New York and High Point, New Jersey forests (Laderman, unpubl.).

Monographs by Nichols (1913) and Taylor (1915), and a master's thesis by Noyes (1939) constitute the major sources of historical botanical data about *Chamaecyparis* in the state. The papers contain lists of associated species, brief site descriptions, and maps, indicating that of 86 cedar stands known at the time, 85% were east of the Connecticut River.

New York State. Before the agricultural and suburban development of Long Island, cedar swamps were believed to form an almost continuous chain from Brooklyn to Montauk Point (Nichols 1913), clustered along the southern edge of the terminal moraine that forms the island's spine. As civilization spread, cedar wetlands declined drastically (Torrey 1843; Harper 1907; Bicknell 1908; Taylor 1916).

The primary cause of cedar loss in Nassau County was lowering of the water table when streams were dammed to create reservoirs for the rapidly expanding populace. Nassau County today holds few mature cedars, with no evidence of regeneration (J. Turner, pers. comm.).

In Suffolk County, earlier in this century, many wetlands were lumbered, drained, and cleared for farming. Those remaining are being rapidly replaced by summer resorts and second homes. The county now contains only 11 known cedar stands, most of them quite small. Southampton Township harbors the greatest abundance of cedars in Long Island. The largest New York wetland complex containing *Chamaecyparis* is in a 40-ha area of Southampton's Cranberry Bog County Park, along the southern reaches of the Peconic River (J. Turner, pers. comm.).

Outside Long Island, the only cedar stands remaining in the state are two small bogs in Sterling Forest, each less than 0.5 ha (Lynn 1984; Lynn and Karlin 1985).

New Jersey. Glaciated New Jersey has only seven known cedar stands, but it bears the distinction of harboring an Atlantic white cedar swamp in High Point at the greatest altitude recorded for the species. Its elevation of 457 m exceeds that of the next highest stand (in New Hampshire) by 69 m. Only three northern New Jersey sites contain more than a few trees at present: High Point and Wawayanda in Sussex County in the far northwest corner of the state, and Uttertown in adjacent Passaic County (D. Snyder, pers. comm.). At least eight other sites in glaciated New Jersey had once supported cedar (Britton 1889; Gifford 1896; Heusser 1963).

The higher elevation areas show no evidence of the existence of earlier, more extensive stands. The Hackensack Meadows, however, was covered by great cedar wetlands which were first described in botanical detail by Torrey and his coworkers (1819). In the mid-eighteenth century, huge fires were set in these swamps to eliminate hiding-places for bandits terrorizing the region. At about the same time, extensive systems of dikes, ditches, and tide-gates were built in a fruitless series of attempts to cultivate the wetlands. *Chamaecyparis* is now completely extirpated in the Hackensack Meadows. The region's original botanical richness and its subsequent decline were recorded by a series of eminent naturalists (reviewed and correlated by Sipple (1971-1972)(Figure 12).

The high-elevation cedar swamp in High Point, protected by the State of New Jersey since 1923, is now buffered by 516 ha of the Kuser Natural Area (New Jersey Bureau of Forest Management 1984). Its 4-6 ha of mixed dense coniferous-deciduous forest grow on a few dm of woody peat (Belling 1977). Great laurel forms most of the dense undergrowth in deep shade; in more open sections, other heath shrubs (primarily Ericaceae) predominate. Herbs are relatively rare and scattered (Niering 1953; Belling unpubl.).

The cedar forests of glaciated New Jersey strongly resemble the most northerly stands of the species. The only report for balsam fir (*Abies balsamea*) in the state, and its sole sighting in a *Chamaecyparis* association outside of Maine is at High Point (Belling 1977). Larch, black spruce, and hemlock occur with *C. thyoides* only within the glaciated portion of the cedar's range.

2.3 THE NORTH COASTAL PLAIN

2.3.1 Jersey Pinelands

Reviews of the literature and much detailed information about Atlantic white cedar in the Jersey Pinelands are contained in the Pinelands National Reserve Management Plan (New Jersey Pinelands Commission [NJPC] 1980); Roman et al. (1987, and unpubl.); and Forman (1979). Buchholz and Good (1982) prepared extensive annotated Pinelands bibliographies with sections indexed for *Chamaecyparis*.

Most of New Jersey's Atlantic white cedar swamps are located in the state's southern pinelands, historically called the Pine Barrens. Cedar stands presently occupy about 8,680 ha, 2% of this 445,000 ha landscape (Roman and Good 1983). Accounts of Stone (1911), Harshberger (1916) and Wacker (1979) suggest that cedar swamp acreage has been declining since European settlement. Historical estimates, although widely variable, document the reduction from a maximum of 40,500 ha (Vermeule and Pinchot 1900; Cottrell 1929; Ferguson and Meyer 1974).

Southern New Jersey's coastal plain is characterized by low relief with streams slowly flowing through an unconsolidated sand/gravel substrate. The cedar swamps generally form narrow borders on streams from headwaters to tidal freshwater. Of 626 discrete cedar swamp patches in the Pinelands, over 90% are less than or equal to 40 ha. A few cedar swamps over 200 ha in area also occur (Zampella 1987).

Poorly drained muck (fine organic) soils usually underlie the Pinelands cedar swamps. Muck depth, generally shallower than in northern glaciated Jersey, is often less than 1 m, ranging occasionally to 3 m. (Waksman et al. 1943).

Undisturbed mature Pinelands cedar stands are dense and even aged, with canopies 15-18 m high (McCormick 1979). Pitch pine (*Pinus rigida*) is an occasional co-dominant. The understory of red maple, black gum (*Nyssa sylvatica*), and sweet bay (*Magnolia virginiana*) may be continuous, relatively sparse, or absent. Highbush blueberry (*Vaccinium corymbosum*), dangleberry (*Gaylussacia frondosa*), swamp azalea (*Rhododendron viscosum*), sweet pepperbush (*Clethra alnifolia*), fetterbush (*Lyonia mariana*), and bayberry (*Myrica pensylvanica*) are the commonest species in the shrub layer. Hollows are conspicuously carpeted with *Sphagnum* spp. The herbaceous flora is usually sparse, but diverse. Sundews (*Drosera* spp.), bladderworts (*Utricularia* spp.), pitcher plant, and chain fern (*Woodwardia virginica*) are the commonest herbs. In New Jersey, the rare curly grass fern (*Schizaea pusilla*) is found only in the Pine Barrens.

Disturbances such as fire, storms (windthrow, ice damage), cutting, flooding, deer browse on young stands, beaver damming, cranberry cultivation, and subsequent abandonment cause considerable variation in the vegetation structure and species composition of Pinelands cedar swamps. Such disturbances may be followed by the growth of cedars in pure stands, in mixed cedar-

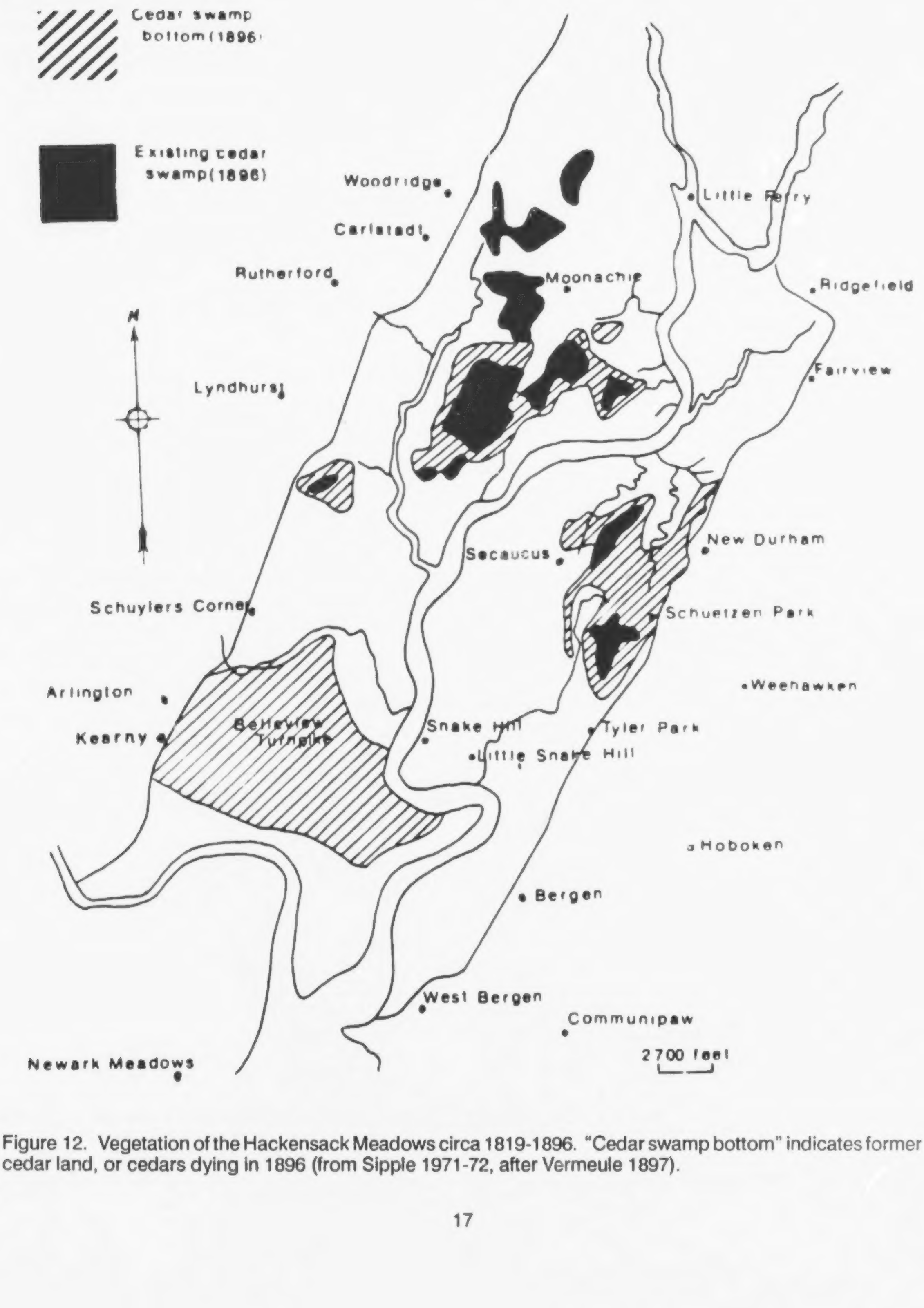

Figure 12. Vegetation of the Hackensack Meadows circa 1819-1896. "Cedar swamp bottom" indicates former cedar land, or cedars dying in 1896 (from Sipple 1971-72, after Vermeule 1897).

hardwood stands, or as isolated trees or clusters in a shrub-dominated landscape (Little 1979; Forman 1979).

Decline of cedar swamps. It must be emphasized that the general trend has been toward conversion to other wetland types. In addition to disturbances noted earlier, the decline of the Pinelands cedar wetlands has been hastened by rising sea level, flooding for cranberry production, creation of industry-related reservoirs and recreational lakes, and drainage for agriculture and residential development (Roman et al. 1987).

The harvest and management of Atlantic white cedar in the Pinelands are discussed in detail in Chapter 6.

2.3.2 The Delmarva Peninsula

Atlantic white cedar exists today on the Delmarva Peninsula in remnant stands that represent only a fraction of the species' former geographic range (Figure 13). For literature review and further detail, see Dill et al. (1987) and Dill et al. (unpubl.), from which the following discussion was extracted.

Just 322 km long and only 113 km at its widest, the Delmarva peninsula contains all three Delaware counties, nine Eastern Shore Maryland counties, and two Eastern Shore Virginia counties. It is bounded on the north by Pennsylvania; on the east by the Delaware River, Delaware Bay, and the Atlantic Ocean; and on the west by the Susquehanna River and Chesapeake Bay. There are two distinct geographic provinces: (1) the Piedmont Plateau, with rocky, wooded hillsides and rich alluvial stream valleys and (2) the Atlantic Coastal Plain, with soils of clays, silts, sands, and gravels.

The Fall Zone cuts across the northern portion of the peninsula in a narrow northeast to southwest band. Here Piedmont streams tumble as much as 42.7 m to the Inner Coastal Plain below. All Atlantic white cedar sites in Delmarva are located below the Fall Zone, with a few stands on the Inner Coastal Plain, and none on the Piedmont Plateau.

A catalog of 58 present and historic sites indicates that white cedar now grows in Kent and Sussex Counties, Delaware; Kent, Queen Ann's, Talbot, Dorchester, Wicomico, and Worcester Counties, Maryland; and Accomac County, Virginia. Cedar wetlands are found in six watersheds draining into Delaware Bay: three drain directly in the Atlantic Ocean, and five drain into the Chesapeake Bay. All sites are associated with acid water (ca. pH 5) on the Coastal Plain, where cedar is found primarily along non-tidal river courses, with a few on pond margins and in isolated swamps. Cedar presence is closely correlated with Delaware soil types (Seyfried 1985).

The average annual temperature is 13° C; average annual precipitation is 114.3 cm. For most of the year, winds are west to northwest, with a more southerly flow in summer.

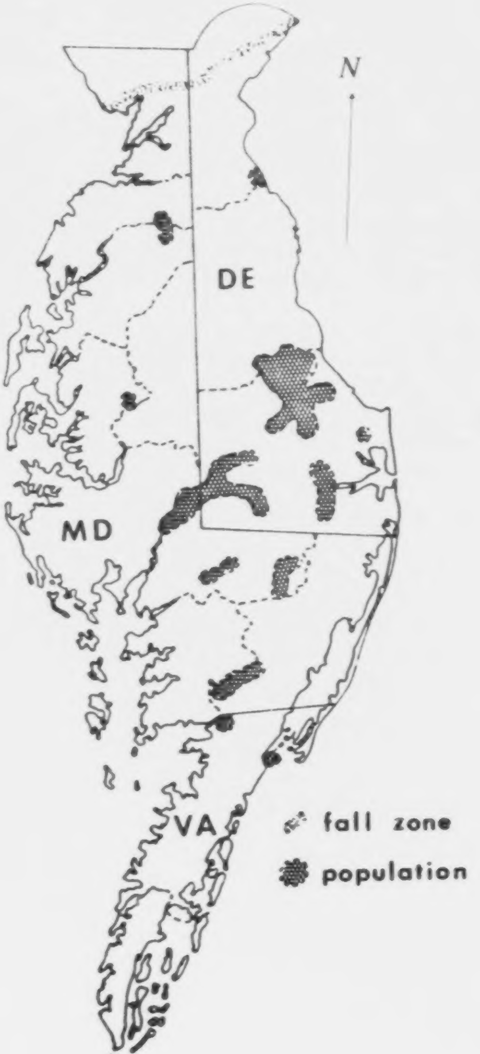

Figure 13. The probable historical range of Atlantic white cedar in the Delmarva peninsula, reconstructed from herbarium records and personal communications (from Dill et al. 1987).

Delmarva habitats are collectively characterized by the presence of 16 plant taxa variously noted as rare in Delaware, Maryland, and Virginia lists (see Chapter 5). Of particular interest is the association of several carnivorous plants; the nationally rare swamp pink (*Helonias bullata*); and the Delmarva endemic, seaside alder (*Alnus maritima*). Human impacts have extended over three centuries and include millpond construction, fire, siltation, drainage and channelization, bulkheading of riverfront property, pollution, and commercial timbering. Existing stands are seen as prime habitats for natural area conservation.

2.4 VIRGINIA AND THE CAROLINAS

On the Virginia mainland, Atlantic white cedar is found only in the Great Dismal Swamp. Virginia's Eastern Shore stands are considered with the rest of the Delmarva area in Section 2.3.2. The historical range of *Chamaecyparis* in North and South Carolina has been documented by Frost (1987 and unpubl.)(Figure 14). Eastern North Carolina is the subject of a case study, Chapter 7.

2.4.1 The Great Dismal Swamp in Virginia and North Carolina

The name "Dismal Swamp" originated in colonial days for the over 404,000 undrained hectares between the James River in southeastern Virginia and the Albemarle Sound in North Carolina (Oaks and Whitehead 1979). The Great Dismal Swamp National Wildlife Refuge (GDSNWR), established in 1973, occupies a 43,000 ha rectangular remnant of the former swamp.

Located approximately 48 km from the Atlantic Ocean, the refuge lies between the cities of Suffolk and Chesapeake in Tidewater Virginia and within Gates, Camden, and Pasquotank Counties in North Carolina (Figure 15). It is delineated on the north by U.S. Route 58, on the south by U.S. Route 158, on the east by Route 17, and on the west by the Suffolk Scarp.

Where no other source is indicated, the following discussion is drawn from the draft environmental impact statement (EIS) for the Great Dismal Swamp National Wildlife Refuge Master Plan (USFWS 1986b).

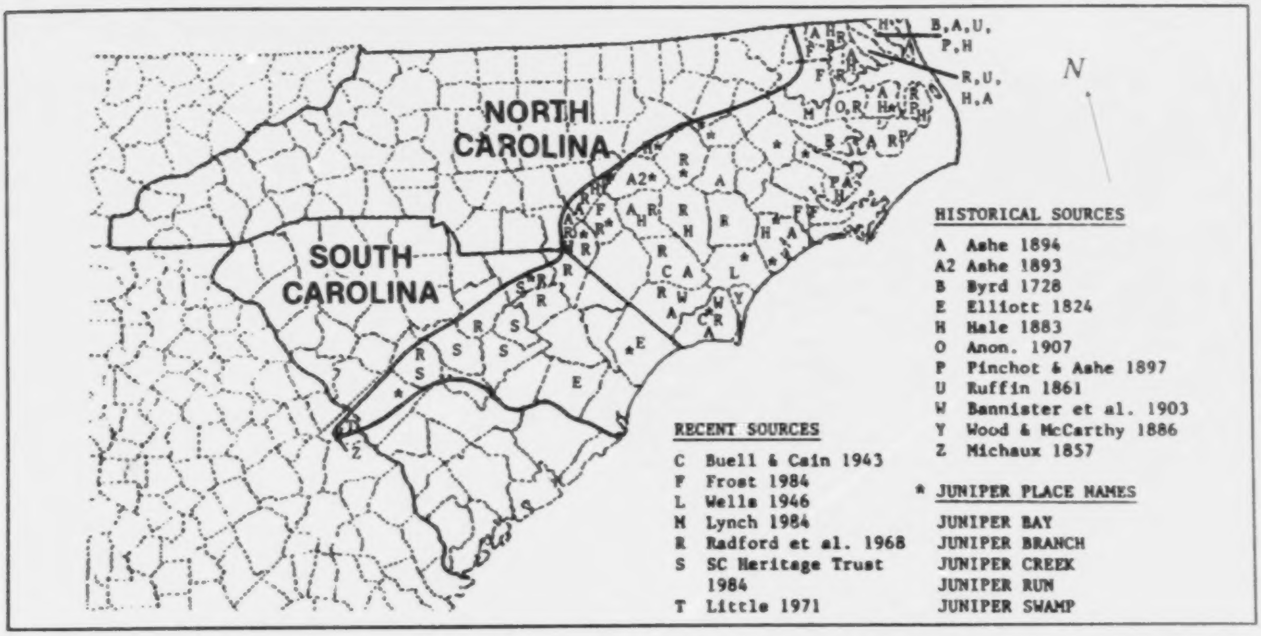

Figure 14. Historical range of Atlantic white cedar in the Carolinas. Letters in each county refer to sources in the literature, herbaria, or place names, as documented in Frost (1987, and unpubl.) (from Frost 1987).

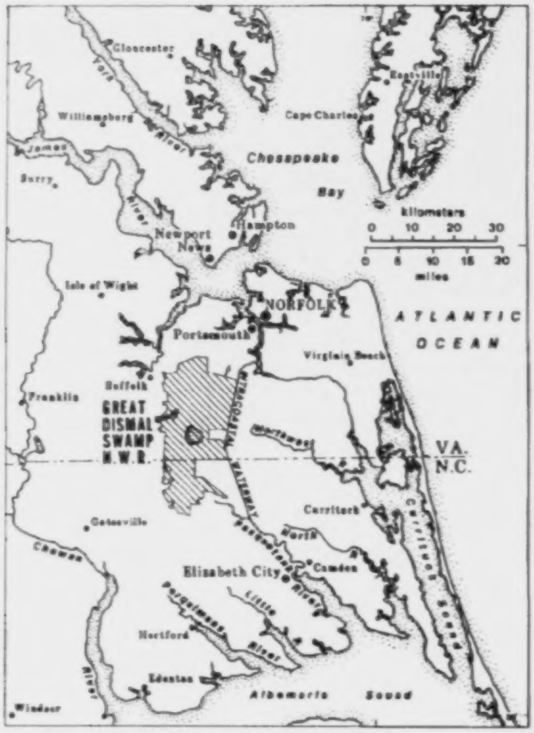

Figure 15. Great Dismal Swamp National Wildlife Refuge, Virginia and North Carolina (from USFWS 1986b).

Development and geography. Although paleogeography of the Atlantic coast is still the subject of debate (e.g., Watts and Stuiver 1980; Bloom 1983), it is generally believed that the Dismal Swamp probably first developed along coastal streams 11,000 to 12,000 years ago (Oaks and Coch 1973; USFWS 1986b). Palynological evidence (Whitehead 1965) indicates that full-glacial boreal spruce-pine forests were succeeded by pine-spruce forests and, toward the end of the late-glacial, by northern hardwood forests. During the early postglacial period, the forests were dominated by hardwoods that currently grow in the region. A variable cypress-gum forest has characterized the Dismal Swamp for the past 3500 years (Whitehead and Oaks 1979). The wetland expanded along watercourses, and peat accumulated until by 3,500 years B.P., peat had blanketed the present-day Dismal Swamp. Whitehead (1965) and Whitehead and Oaks (1979) found that cypress (*Taxodium*) and cedar pollens first appear in the peat about 6,500 yrs B.P., increasing to 60% of pollens by 3,000 yrs B.P. Since then, cypress and cedar have comprised 40%-60% of the peat pollen profile. (*Chamaecyparis* pollens were not counted separately.)

Climate, physiography, topography, and geology. Temperatures, precipitation patterns, and humidity are similar to that of Dare County, North Carolina (see Chapter 7). The Dismal Swamp lies on the Atlantic Coastal Plain, between the Suffolk Scarp and the Deep Creek Swale. Elevations range from 4.6 to 7.6 m. The topography slopes gently to the east at the rate of 0.2 m/km (Carter 1987).

The geologic formation most intimately associated with the Dismal Swamp water budget, which accounts for the majority of water that upwells in the swamp, is a shallow aquifer composed of coarsely-grained to finely-grained old marine sands (Lichtler and Walker 1979). Formerly termed the Norfolk Formation (now recognized as the Shirley and Tabb Formations [Carter 1987]), this is a water-bearing layer through which water moves laterally.

Soils. The soils of the cedar swamps are black, fine-grained, highly decomposed mucky peats characterized by poor drainage and high acidity, with mean annual soil temperatures between 15 and 22 °C. Undecomposed logs and stumps are buried in the decomposed organic material at depths ranging from a few centimeters to 1.5 m (Lichter and Walker 1979; Otte 1981). Permeability varies with the composition of the subsoil.

Hydrology. As the wetland district's hydrological functions are interrelated, and data restricted to the cedar stands are unavailable, information on the water regime of the entire Dismal Swamp (Lichtler and Walker 1979; USFWS 1986b; P. Gammon, pers. comm.) is examined here.

Inflow. Ground water (a major influence) flows into the swamp from the west through permeable layers that interface with the shallow "Norfolk" aquifer. The average annual precipitation is 127 cm (U.S. Weather Bureau 1926-1975, quoted in USFWS 1986b). Surface water inflow from the west along the Suffolk Scarp is a minor influence, with most of it moving out rapidly through streams and ditches.

Water loss. Evapotranspiration (the combined effects of evaporation and transpiration) in areas upstream (i.e., west) of the swamp severely limits inflow during summer months despite high rainfall. In the summer months, evapotranspiration probably accounts for the biggest portion of water removal from the swamp ecosystem. It exceeds rainfall during the growing season and causes a lowering of water levels in the swamp throughout the summer. Surface water runoff through the swamp is also a major output event. Over the last two centuries natural outflow patterns have been almost completely obliterated, and surface water now drains from the swamp through channelized outlets. Ground-water discharge is significant: where the upper confining layer is absent, freshwater wells up into the overlying peat and is removed by evapotranspiration; where the aquifer is breached, ground water drains from the swamp as surface flow through outlet channels. In the latter case, the water is lost to the swamp; it may be a major factor in the lowering of the swamp's general water level.

The net effect of all the modifications to the swamp's surface and ground water systems is that the majority of the peat soils in the swamp are drier for a longer period of the annual cycle than would occur naturally (Lichtler and Walker 1979; USFWS 1986b).

Surface water. The water has a dark tannic color, low mineral content, and a pH of 3.5 - 6.7. Some areas have high iron and free carbon dioxide content. Sediment from upstream agricultural and timber lands, runoff from hog operations, and fertilizers and pesticides used on corn, soybeans, and peanuts are potential sources of surface water pollution. The proximity of the shallow aquifer to the surface makes it highly susceptible to contamination from agricultural, industrial, and domestic runoff.

Biota. Atlantic white cedar covers 3,000 ha or 7% of the refuge, primarily in the south central portion of the swamp, with a few stands north of Lake Drummond. At present, it is impossible to estimate the area occupied by cedar a century or more earlier (A. Carter, pers. comm.). In the Great Dismal, cedar grows primarily either in pure, even-aged stands or mixed with red maple, black gum, sweet bay, and red bay (*Persea borbonia*) or pond pine (*Pinus serotina*).

The Great Dismal contains three major swamp forest communities in addition to the cedar stands:

a. Maple-Gum, dominated by red maple and black gum, often in association with red bay, sweet bay, sweet gum (*Liquidambar styraciflua*), and the tulip-tree (*Liriodendron tulipifera*). Maple-gum now covers 60% of the Great Dismal, having increased significantly in the past 40 years at the expense of both cypress-gum and cedar associations.

b. Cypress-Gum, dominated by cypress (*Taxodum distichum*), tupelo gum (*Nyssa aquatica*), and black gum. This was formerly the most extensive association in the swamp.

c. Pine, dominated by either loblolly or pond pine.

Over time, the composition of the swamp forest varied. In the Great Dismal, the continuing effects of human activities in the swamp now override natural influences on succession. Cedar has been harvested on a large scale in the Dismal Swamp since the 18th century when the Dismal Swamp Land Company began operations. Loggers often cut the cedar but left the hardwoods to take over the site, or left so much slash on the ground that cedar seedlings were unable to develop in the resultant shade. Other important factors that have resulted in the gradual succession to hardwoods are suppression of wildfires and changes in the water regime (see Chapter 6). Frost (1987 and unpubl.) and Ward (unpubl.) discuss Great Dismal commercial cedar logging operations in detail.

Despite major disturbances, the swamp still contains typical historical communities whose existence predates the extensive development of the 1940's and 1950's. Many of the historical species in the swamp appear to have survived, but their relative abundance has changed. The five herbaceous species classified as rare or endangered in the cedar wetlands of Virginia (Porter 1979) all occur exclusively in the Delmarva peninsula.

The vascular flora associated with cedar in the Great Dismal, currently consisting of 19 tree, 34 shrub, and 7 herbaceous species (A. Laderman, unpubl.) is included in Appendix A; some frequently encountered species are illustrated in Figure 24. Wildlife on the refuge is discussed in Section 5.3. A list of Great Dismal flora and fauna is maintained by the Refuge staff; the tabulation of 1979-1980 is contained in the Refuge Master Plan (USFWS 1986b). Levy and Walker (1979) examined forest dynamics in the Great Dismal's cedar wetlands. Day and his co-workers have conducted a series of studies on community structure, biomass, productivity, and decomposition rates of a Great Dismal cedar wetland from 1977 to the present (synthesized and summarized in Day 1987 and unpubl.). Extensive discussions of all aspects of the Great Dismal, including literature reviews, appear in the proceedings of a 1973 conference devoted to the subject (Kirk 1979) as well as in USFWS (1984a and 1986a,b). For further discussion of flora and fauna of the region, see Chapter 5.

Management. Burning, grazing, and logging that once maintained parts of the Great Dismal Swamp in different stages of succession or climax were curtailed or eliminated when the Refuge was established. Drainage from 224 km of ditches and the soil compaction and damming effect of 252 km of roads, exacerbated by accelerating rates of upstream runoff, have seriously lowered the water table in many areas and impounded and flooded others. The net effect has been to progressively replace the distinctive cypress and Atlantic white cedar communities by a relatively uniform red maple-black gum forest. An extensive master plan was developed by the U.S. Fish and Wildlife Service (USFWS 1986b) in an effort to reverse this trend. Key aspects of the proposed management program (in review at the time of this writing) are outlined in Chapter 6.

2.4.2 South Carolina

Information on South Carolina cedar wetlands flora and its distribution was provided by J. Nelson (pers. comm.) and D.A. Rayner (pers. comm.). Early records of the botanical and logging history of North and South Carolina are described by Frost (1987 and unpubl.)(Figure 14).

Radford (1976) lists five counties in South Carolina having populations of white cedar: Lexington, Kershaw, Chesterfield, Darlington, and Marlboro. Populations are also known from Horry, Georgetown, Richland, and Sumter Counties, and it is very likely that white cedar is also present in Aiken County. All but two of these counties are part of the midlands of South Carolina, where extensive acreages of xeric sandhills are associated with palustrine communities. Francis Marion National Forest contains a few small cedar stands.

The South Carolina Heritage Trust data base places *Chamaecyparis* habitats within the "Atlantic White Cedar Bog" community. All the sites found within sandhill areas are quite similar (J. Nelson, pers. comm.). They always seem to be associated with creek drainages and may extend for several miles near the base of a slope at the creek edge. White cedar forms dense forest at times and sometimes moves onto the sides of the adjacent hills, especially if there is a hardpan of ironstone near the top that forces water out along the slopes as intermittent seepages. The water within the sandhill creeks is either clear or tea-colored: its color appears to be related to the size of the stream itself and the distance it has flowed from its headwaters.

In very wet areas, abundant Sphagnum is found with lady's slipper (*Cyprepedium acaule*), cinnamon fern (*Osmunda cinnamomea*), and sedges (especially *Rhynchospora* spp.). Golden club (*Orontium aquaticum*), tuckahoe (*Peltandra virginica*), and pitcher plant (*Sarracenia rubra*) are also found. Shrubs in these bogs usually include fetterbush (*Lyonia lucida*), gallberries (*Ilex* spp.), blueberries (*Vaccinium* spp.), titi (*Cyrilla racemiflora*), and greenbrier (*Smilax laurifolia*). *Vaccinium sempervirens*, a low shrub thought to be endemic to some Lexington Carolina bays are a wetland type of unknown origin primarily restricted to North and South Carolina. The bays, dominated by evergreen shrubs, form elongated elliptical depressions on a northwest, southeast axis (Richardson 1981).

County drainages, co-occurs with Atlantic white cedar (Rayner and Henderson 1980). Red maple, red bay, loblolly bay (*Gordonia lasianthus*), sweet bay, and black gum are frequently seen tree species which sometimes occur as large, branched shrubs. Pond pine is occasionally present. In general, these bogs tend to have essentially the same sort of vegetation as many of the pocosin sites in South Carolina, but with a higher and thicker canopy, and perhaps a less diverse shrub layer.

An unusual white cedar wetland, with a different suite of species, is found in Sumter County. There is also at least one large Carolina bay in South Carolina (on the bombing range of an Air Force base) containing large white cedars. Carolina bays are a wetland type of unknown origin primarily restricted to North and South Carolina. The bays, dominated by evergreen shrubs, form elongated elliptical depressions on a northwest, southeast axis (Richardson 1981). A cross section through a Carolina bay with *Chamaecyparis* is shown in Figure 16.

2.5 JUNIPER SWAMPS OF THE SOUTHEAST

2.5.1 Overview

Atlantic white cedar reaches its southernmost distributional limits in Florida and along the gulf coast of Alabama and Mississippi (Figure 17). The cedar of Mississippi, Alabama, and western Florida differs in some vegetative and reproductive characters from that in eastern Florida and northward. Although controversy surrounds its taxonomy (A. Gholson, pers. comm.; Li 1962), the accepted designation is *C. thyoides* var. *henryae* (E. Little 1966). Literature on Atlantic white cedar in Florida and along the gulf coast is sparse. Ward (1963) and Collins et al. (1964) briefly described the two southernmost stands of the species, which are both in peninsular Florida. Despite the fact that the largest cedar living today grows in Alabama (see Section 3.2.4), as of this writing scientific literature on Atlantic white cedar in that state is virtually nonexistent. In 1791, William Bartram described strange cedars growing along the Escambia River, noting their similarity to, and differences from, the white cedar of New Jersey. Eleuterius and Jones (1972) examined white cedar stands in Mississippi, at the western edge of its range. A comprehensive literature review and a substantial body of hitherto unpublished data on the region's cedar wetlands were recently gathered by Clewell and Ward (1987) and Ward and Clewell (unpubl.), from which much of the following information is drawn.

2.5.2 Georgia

Only two white cedar stands are known in the state, both in west-central Georgia: one grows along a tributary of Upatoi Creek in Talbot and Marion Counties; the other borders Whitewater Creek in taylor County (W. Duncan, pers. comm.). Both stands are on sandy terraces in the east-west belt of Fall Line sandhills along streams that flow southward into the Apalachicola River.

2.5.3 Florida

The southernmost white cedar stand is in northeastern peninsular Florida, along Juniper Creek and its tributary, Morman Branch, in the Ocala National Forest, Marion County. About 45 km to the north, a second peninsular Florida stand lies along Deep Creek in Putnam County. Both populations flank spring-fed streams that discharge ultimately into the St. Johns River. These are the only stands within Florida's Atlantic watershed. All other populations, including those in Georgia, are in the Gulf of Mexico drainage.

In the central Florida panhandle, a cluster of cedar stands is associated with streams largely within the watersheds of the Ochlockonee and Apalachicola rivers. Another population center is located in the western Florida panhandle and Alabama, in association with several streams that independently flow to the gulf. The westernmost stands lie along several streams in southern Mississippi.

In its southern range, white cedar is conspicuous and often dominant wherever it grows. Paradoxically, populations are often small and isolated, even though the cedar's typical habitats are relatively widespread.

Autecology. Growth requirements for white cedar in the Florida panhandle generally are similar to those of the Atlantic seaboard provinces, except with regard to hydrology, fire, and pH (Clewell 1971, 1981). White cedar in the south is found where there is little flooding and siltation, on the banks of small

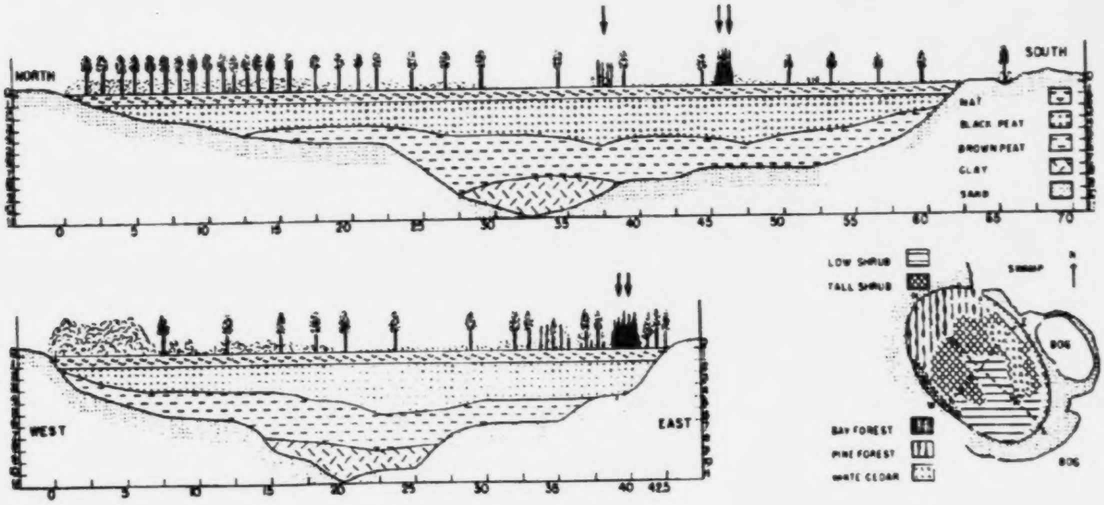

Figure 16. Section and plan views of a Carolina bay with Atlantic white cedars, indicating morphological features, soil profiles, and vegetation types. Single arrow points to clump of dead cedars; double arrows point to living cedar forest (modified from Buell 1946).

perennial streams (Figure 18) and in the back swamps of larger streams, i.e., far from the main channel. Cedars are absent from large-stream floodplains where alluvial deposits are heavy and seasonal water level fluctuation is great.

Atlantic white cedar in peninsular Florida and west along the gulf coast is almost never found in even-aged stands, although it often overtops associated hardwoods and is frequently a dominant component of the canopy. The uneven-aged, mixed-species stands typical of the southern white cedar forests are a consequence of gap succession (revegetation under openings in the canopy) in the absence of fire (Clewell and Ward 1987).

In contrast to the acid soils in which *Chamaecyparis* is usually found from North Carolina northward, soil pH of 6.6 to 7.5 has been recorded in Putnam and Marion Counties in peninsular Florida (Collins et al. 1964; Clewell and Ward 1987).

Fires are less frequent or at least less destructive than in the northern range of the species, due to the incised topography, the constantly moist soils and leaf litter, and the intermixture of relatively poorly burning vegetation of other species. Clewell and Ward (1987) believe that the relative rarity of destructive fires in these southern stands favors a mixed forest of white cedar, dicotyledonous hardwood, and sometimes palm, rather than monospecific stands of white cedar. Herbaceous species are often much more numerous than in northern stands.

Ward and Clewell (unpubl.) report that lightning, which is particularly frequent in the Florida peninsula, appears to be the major cause of the death of mature cedars there. No white cedars have been reported to survive a lightning strike.

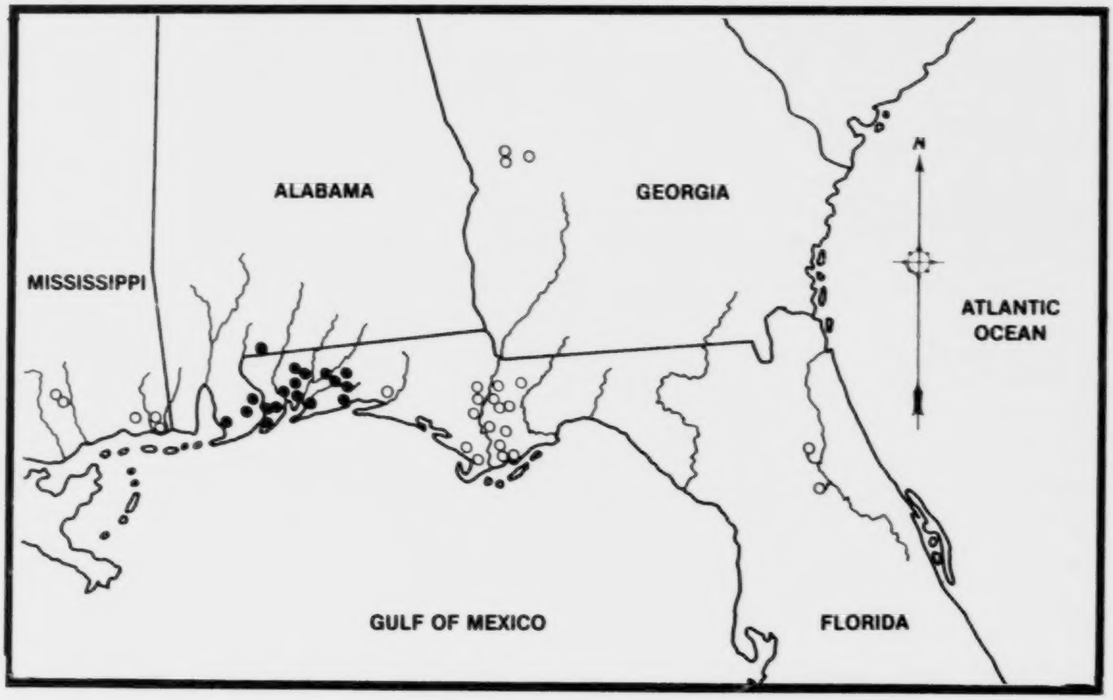

Figure 17. Atlantic white cedar in Southeastern United States, documented by herbarium specimens and field work. Open circles represent stands of typical *C. thyoides*; solid circles represent *C. thyoides* var. *henryae* (modified from Clewell and Ward 1987).

2.5.4 Mississippi

The following information is drawn from Eleuterius and Jones (1972) unless otherwise noted.

The westernmost known extension of Atlantic white cedar is a small stand along Juniper Creek near Poplarville in Pearl River County, Mississippi. This mixed stand has been considerably disturbed and was actively logged.

The largest stand in the state grows along Bluff Creek in the small community of VanCleave (Jones 1967). Most of the 11.2 km-long stand is below 3 m elevation, with cedars intermixing with pine and hardwood forest at about 6 m. On the south side of the creek, some cedars grew on a steep bluff at 18 m elevation. The widest part of the stand was about 0.8 km. Cedars grow on bluffs of various heights, levees, bogs behind the levees, and on gently sloping floodplain areas that end on white cedar covered sand bars. The largest cedar seen was ca. 30 m high and 71 cm in diameter.

Better-drained areas in the Bluff Creek area are dominated by pine or hardwood forest; perennially inundated areas are dominated by cypress or black gum. On intermediate areas white cedar forms a mature uneven-aged monotypic stand. In 1967, large numbers of cedar seedlings and vigorous saplings were present in the cedar and pine-dominated areas and in a 45 m-wide fire lane. Many of the mature cedars were heavily infested with the galls and witches' brooms of the rust fungus *Gymnosporangium*; many trees have been damaged or chopped for firewood.

The most abundant associated tree species were: slash pine (*Pinus elliottii*), black gum, cypress (*Taxodium distichum*), American holly *(Ilex opaca)*, and red maple. Shrub species were highly diverse: Eleuterius and Jones (1972) classed 21 species as "important." The most important shrubs near the creek were the titis *(Cliftonia monophylla, Cyrilla racemiflora)*; further up the slope, farkleberry *(Vaccinium arboreum)*, Elliot's blueberry *(V. elliottii)*, large gallberry *(Ilex coriacea)*, cassine *(I. vomitoria)*, and red bay were most abundant in the shrub story.

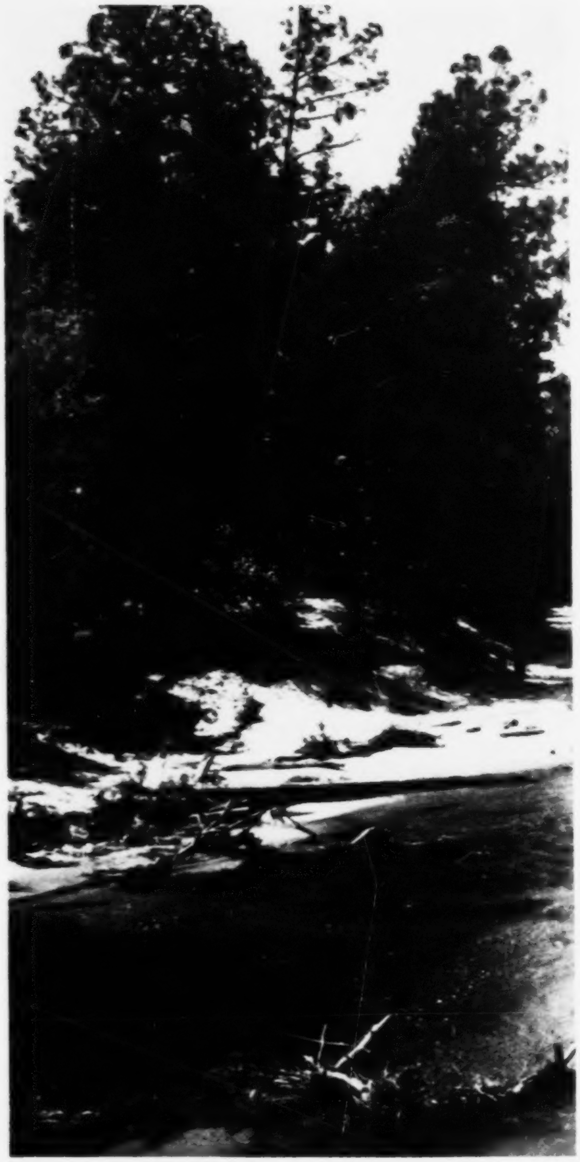

Figure 18. Atlantic white cedar growing on the banks of a Florida sand-bottom creek (photo courtesy of A. Simmons).

- CHAPTER 3 -

CHAMAECYPARIS THYOIDES: LIFE HISTORY AND ECOLOGY

The morphology, growth, and ecology (or silvics) of Atlantic white cedar have been examined in detail by Korstian (1924), Korstian and Brush (1931), and Little (1950). Most work published on the subject since 1950 has been based on the data of these studies (e.g., Fowells 1965; Little and Garrett, in press). Table 2 contains a summary of the life history of *C. thyoides;* morphology of its branchlets, leaves, and reproductive structures is illustrated in Figure 19.

3.1 MORPHOLOGY

3.1.1 The Tree

Atlantic white cedar is a graceful, symmetrical conifer. The crown is formed of slender, horizontal branches with slightly pendant sprays of twigs and branchlets. The flexible terminal shoot, or leader, often droops before the wind. In closed

Table 2. Chamaecyparis thyoides: A summary of life history. Data from Harris (1974).

Synonym	Common names	Occurrence	Uses
Cupressus thyoides L.	Atlantic white cedar, white-cedar, false-cypress, swamp-cedar, southern white-cedar, juniper.	Narrow coastal belt from southern Maine to northern Florida, west to southern Mississippi.	Timber production Habitat for wildlife Environmental forestry

Phenology of flowering and fruiting:

Flowering	Cone ripening	Seed Dispersal
March-July	September-October	October 15 to March 1

Height at maturity	Year of first cultivation	Minimum seed bearing age	Interval between large seed crops	Color of ripe cones
12-27 m	1727	3-20 yrs	1 or more years	greenish with glaucous bloom to bluish-purple and very glaucous, finally red-brown.

Yield data:

Yield of seed per 100 pounds of cones	Cleaned seeds per pound		
	Range	Average	Samples
10 pounds	420,000-500,000	460,000	11

Germination: 84% (11 samples) Test conditions: 60 days @ 30 °C days; 20 °C nights stands, the mature cedar has a long, clear, almost cylindrical bole which rapidly tapers within a short crown. The crown in dense stands is typically short, narrow, and conical, usually covering the upper 30% of the trunk. Open-grown trees are more tapered, with longer crowns and more limbs than those growing in a dense stand (Korstian and Brush 1931).

3.1.2 Roots

The root system of *C. thyoides* is shallow and spreading, penetrating only the upper 0.3 to 0.6 m of peat when the substrate is permanently saturated. Roots extend deeper when the water table is not as near the surface.

3.1.3 Leaves

The mature leaves are flat, small, overlapping scales with a prominent resin gland and numerous ring structures. The microscopic structure of cones, leaves, seeds, and pollen is described by Belling (1987).

3.1.4 Flowering and Fruiting

Atlantic white cedar is monoecious, but the staminate (male) and pistillate (female) flowers are produced on separate shoots. Flower buds are formed in spring in the Virginia-North Carolina area (Korstian and Brush 1931) and in summer in southern New Jersey (Little 1941). When mature, the four-sided, oblong, brown staminate flowers are about 3 mm long. The pale green 3 mm-wide pistillate flowers are borne on short lateral branchlets of terminal shoots (Korstian and Brush 1931)(Figure 19).

Pollen. Pollen grains are spheres 21 to 24 μm in diameter with an outer sculptured wall. As the pollens of C. thyoides, arbor-vitae (Thuja occidentalis), and red cedar (Juniperus virginiana) are superficially indistinguishable in form (Belling 1977, 1987), the three species have been recorded by palynologists as "cedar" (Cupressaceae) despite their significant differences in habitat.

The light-green angular six-sided cones mature in early autumn and become dark red-brown the following year.

Seeds. The 3 mm-long, flat, rounded seeds are encircled by a darker winged membranous margin. There are ca. 1,014,000 seeds/kg; the average weight per thousand is 0.96 g.

3.2 SILVICAL HABITS

3.2.1 Seed Production and Dissemination

Production. The onset of seed production varies greatly with environmental conditions: the climate, water level, substrate, and competition with other cedars and other species. Little (1950) observed that the onset of cone-bearing in New Jersey cedars in natural stands ranged from 7 years on 0.24 m trees through 22 years on 1.28 m trees. Nursery-grown field transplants produce seed as early as 3 years after germination.

Little (1950) noted that trees growing in the open tend to produce more cones than those in clumps, although dominant trees in clumps may be as prolific as open-grown trees of the same size. The amount of seed produced varies from year to year; abundant crops occur at about 2- or 3-year intervals (Cottrell 1929; Little 1950).

Dissemination. Seed dispersal is influenced by weather (temperature, relative humidity, rainfall, wind direction, and velocity), the height and diameter of the parent tree, and the density and height of surrounding vegetation. Seed dispersal starts in early autumn; most of the seed is released before the end of winter. In New Jersey, the peak of seedfall occurs in a 2-week period in late October and early November (Little 1941).

In seed-trapping experiments, Little (1950) confirmed that density and height of the surrounding vegetation can almost completely prevent the dispersal of seeds beyond the edge of a stand. Seedfall per unit area decreases greatly as distance from the tree increases. Heavy rainfall causes complete closing of the cones; lighter rain reduces the rate of seedfall due to the partial closure of cones (Little 1940). High winds increase the quantity of seeds falling; wind direction also greatly affects seed movement (Little 1940).

Seed viability. Seed viability is highly variable. The most important factors appear to be the age, genetics, general health, and nutrition of the parent tree; climate; and weather. The first seed crops of a tree have a lower average germination rate than later production.

Germination. Under natural conditions, much white cedar seed does not germinate until the start of the 2nd or 3rd growing season after seed fall (G. Emerson 1846; Moore 1939; Little 1950). Overwinter storage in a cool, moist medium, such as the moss and peat of a swamp floor, apparently promotes germination.

3.2.2 Seedbed Conditions

Moisture. As early as 1923, Akerman described in detail the importance of swamp microrelief in providing suitable cedar seedbed. He observed that only the logs, stumps, or hummocks that are above water during the spring high-water periods form favorable seedbeds, but seedlings starting there may die from lack of moisture during later dry periods. However, seedlings growing in lower places frequently drown during subsequent high-water periods. Akerman concluded that seedlings sprouting at intermediate positions had better survival than those starting either at the highest or lowest spots. He found that root development by the end of the first growing season began to make seedlings drought-resistant, but they remained susceptible to drowning until after the second growing season, when many were more than 30 cm tall. These observations have been repeatedly corroborated (e.g., Korstian and Brush 1931; Little 1950). Little (1950) determined experimentally that seedlings survive in hollows only when they are above the water table.

Seedbed. Suitable substrates include rotten wood, peat, and *Sphagnum* moss. Hardwood and shrub leaf litter and pine needles inhibit cedar germination to less than one per cent. Seeds may germinate in mineral soil, but non-organic soil is not as favorable as hardwood swamp peat, where rates are as high as 49%, and dominant first-year seedlings are more than three times taller than on mineral substrate. The floor of a wetland previously supporting Atlantic white cedar is the most favorable substrate.

Light. Relatively open conditions are necessary for healthy growth of *C. thyoides* seedlings, although they may survive for 1 to 3 years under a mature cedar canopy, where light intensity averages 4% to 6% of full sunlight. Canopy thinning enables white cedar seedlings to live longer, but they are still out-competed by shrubs and other trees. At a light intensity of 77%, initial growth of seedlings was double that at 16% light, and almost quadruple that at 2% intensity (Little and Garrett, in press). Warm open areas, such as cleaned clearcut cedar stands, abandoned cranberry bogs, recent burns over water-

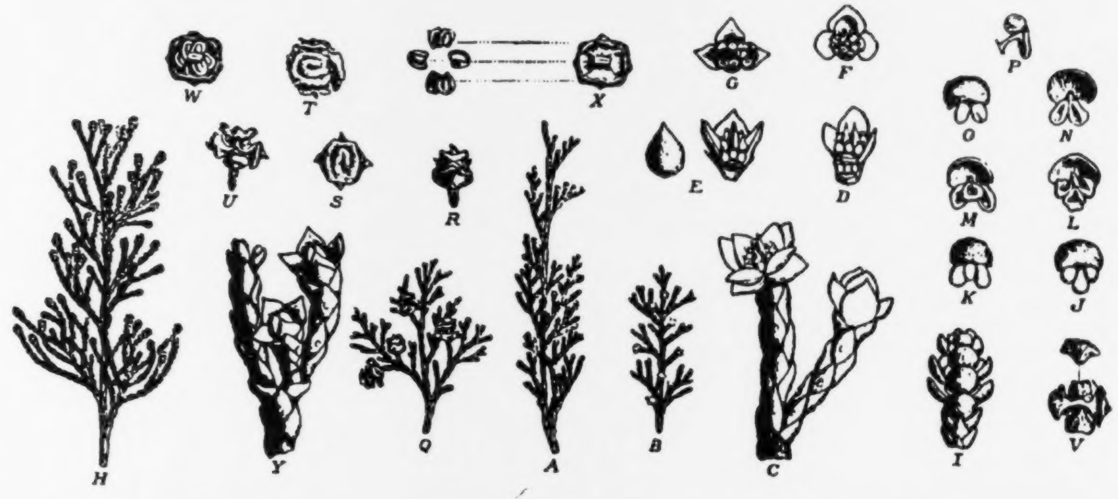

Figure 19. Morphology of *Chamaecyparis thyoides*. A, B, H, and Q are reduced in size; all others are magnified (from Korstian and Brush 1931).

A-C.	Branchlet with pistillate flowers.
D-G.	Pistillate flowers (longitudinal and cross sections).
H.	Branchlet with staminate flowers.
I.	Tip of H, magnified.
J-O.	Anthers bearing pollen sacs (surface and section views).
P.	Cross section of stamen attached to filament.
Q.	Branchlet with mature fruit.
R-X.	Branchlet showing arrangement of leaves, glands on scales.
Y.	Mature cones (top, side, and dissected views) with seeds intact and discharged.

filled swamps, or peatlands partly drained after flooding, provide satisfactory conditions for white cedar reproduction (Korstian and Brush 1931; Little 1950).

3.2.3 Growth Rates

Seedlings. Little (1950) determined that early growth varies greatly with substrate and light conditions, with first year increments ranging from 2.5 cm to as high as 25 cm. Thereafter, seedlings may grow more than 0.3 m annually on favorable sites. This results in 3 m saplings in 7 or 8 years in the South, and in about 10 years in southern New Jersey. On unfavorable substrate, growth in 15 years may be only 1.2 m.

Mature trees. Korstian and Brush (1931) published extensive life table data for natural- and field-grown cedars. In the single controlled study of mature Atlantic white cedar growth rates published, Golet and Lowry (1987) observed that cedars in Rhode Island swamps grow an average of 0.79-1.79 mm/yr radially, primarily during March through August (Figure 20). They found that yearly variations in growth within individual cedar swamps may be related to water level variations, but this relationship differs markedly from wetland to wetland. They observed no general relationship between water regime and annual radial growth. Cedar growth seemed more closely linked to ground water chemistry and forest stand characteristics than to the hydrological regime.

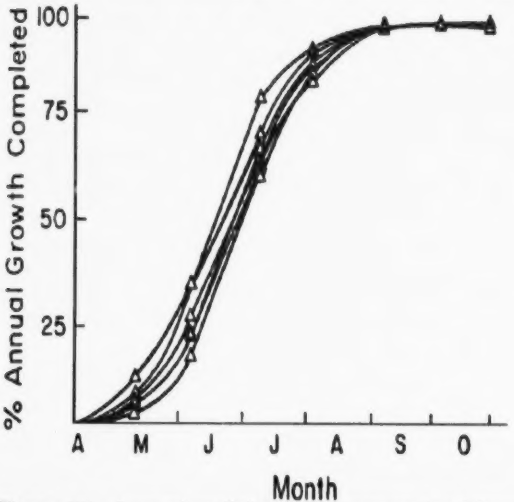

Figure 20. Annual radial growth curves for Atlantic white cedar in six Rhode Island swamps. Each point represents the mean of three trees; each line represents one site (from Golet and Lowry 1987).

Vegetative reproduction. In natural settings, cedar sometimes develops lateral or basal shoots after injury. Seedlings repeatedly browsed by deer develop multiple stems through layering (Little 1950; A. Laderman and J. Moore, unpubl. field notes). However, layering stems appear to grow much more slowly than the original growth, and, unlike often vigorous hardwood sprouts, these stems never form an important forest component (Little 1950).

Almost from the time the species was first described, it was known that Atlantic white cedar propagates well from cuttings (letters of J. Bartram in Darlington 1857). The preparation of seedbed, seed, and cuttings for propagation, as well as the influence of competing vegetation on seedling success are discussed under management (Chapter 6).

3.2.4 Maximum Size and Age

The Atlantic white cedar reaches its maximum size in the southernmost part of its range. The "champion" tree now living is in Escambia County, Alabama, on a tributary of the Escambia River. It measures 26.5 m tall and 150 cm dbh and is estimated to be ca. 268 years old (Hunt 1986 [measured in 1961]; Hartman 1982; J. Arany, pers. comm. [measured in 1985]). Trees approaching the Alabama champion in stature have been recently reported in Florida (Wills and Simmons 1984; Ward and Clewell, unpubl.).

Clewell and Ward (1987) report that direct counts of the annual rings of the largest trees have not been possible, for increment tools fail to penetrate properly, and no record-sized trees have been recently cut. The largest trees in Mississippi and Florida are possibly 150 to 190 years old as extrapolated from the minimal data available on growth rates.

The maximum size of *Chamaecyparis* decreases from its mid-range northward, e.g., the maximum heights reported for North Carolina/Virginia were 36.6 m; for southern New Jersey 21.3 m; and for New Hampshire only 12.5 m.

- CHAPTER 4 -

STRUCTURE AND FUNCTION OF THE SUBSTRATE

4.1 HYDROLOGY

The hydrology of cedar wetlands is a controlling factor in aeration of the root zone, availability and movement of nutrients, soil temperature regime, and the availability of moisture. Data on all quantitative and functional aspects of cedar forest water regimes are sparse and fragmentary. Some water regime information is included in other studies on cedar wetlands, e.g., Laderman (1975, 1980) for MA; Little (1950), Markley (1979), Schneider and Ehrenfeld (1987), and reviewed by Roman et al. (unpubl.) for NJ; Dill et al. (unpubl.) for Delmarva; reviewed in USFWS (1986b,c) for VA and NC; and Dunn et al. (1987) for FL. The most comprehensive information available on hydrological functions in a cedar wetland relates to the Great Dismal Swamp (see Section 2.4.1).

4.1.1 Annual Hydrological Cycle

Although the natural water regime varies from year to year, from site to site, and with the development of a stand, a summary of a generalized annual cycle (Otte 1981; Golet and Lowry 1987) would be as follows:

In late winter and early spring, cedar swamp waters are highest. In late spring and early summer, evapotranspiration removes large quantities of water; the water table begins to drop below the ground surface in places. In autumn, swamps are driest, with standing water and water tables at their annual low point. Most water loss is via evapotranspiration. In flowing systems, downstream flow is reduced or absent. In the winter, with declining temperatures and reduced evapotranspiration, the water table rises; in flowing systems, stream flow swells and lateral subsurface and surface flow increases.

4.1.2 Classification of Water Regimes

Chamaecyparis thyoides usually grows on hummocks slightly elevated above and surrounded by hollows where water level may be up to 1.2 m deep, or as low as 0.3 m below the surface. The hollows are saturated or hold standing water for extended periods during the growing season. Cedars themselves are stressed and do not thrive when the bole is under water, but classification (USFWS system, Cowardin et al. 1979) of cedar-dominated wetlands is determined by the water regime in the hollows. Atlantic white cedars are found with the following water regimes:

a. Nontidal: Almost all Atlantic white cedars grow beyond tidal movements. In the living swamps where there is tidal influence (e.g., on the coastal fringes of New Jersey, Delaware, Maryland, North Carolina), tidal flux is very small and infrequent (see Section 7.2.6).

b. Seasonally Flooded: Surface water is present for extended periods especially early in the growing season but is absent by the end of the season in most years. When surface water is absent, the water table is near the land surface.

c. Saturated: The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present. Cedars growing on seepage slopes, or on slopes adjacent to hummock and hollow terrain, also fall in this category.

d. Semipermanently Flooded: Surface water persists throughout the growing season in most years.

e. Permanently Flooded: Water covers the land surface throughout the year in all years.

Some Atlantic white cedars grow in artificially or naturally modified wetlands which are classified with special modifiers to indicate their status: Excavated (with artificially altered channels or basins); Impounded (created by a barrier or dam made by humans or beavers); Diked; Partly Drained (where the water level has been artificially lowered, but soil moisture is sufficient to support hydrophytes).

4.1.3 Hydrological Regimen

Water table activity varies considerably among cedar forests, and from year to year. Golet and Lowry's (1987; Lowry 1984) 7-year study of the hydrological regimen of six Rhode Island cedar swamps is the first long-term research to be published on this subject (Figure 21). They found the mean annual water level varied between 13 cm above to 11 cm below the ground surface (ave. 0.7 cm above). The forest surface was flooded from 18% to 76% of the growing season. Mean annual water table fluctuation ranged from 17 cm to 75 cm, with great variation between swamps. Precipitation variations accounted for 85%-92% of water level variation during the growing season. However, the effect of ground water inflow statistically outweighed that of precipitation in two sites. Cedar-dominated swamps have generally higher water levels than nearby red maple swamps (Reynolds et al. 1982; Lowry 1984) and are flooded for longer periods (Lowry 1984).

During the wettest year of Golet and Lowry's study, when total precipitation was 157.4 cm, water levels in four of six sites studied were above the surface all year (Figure 21). In the driest years (97.0 and 102.8 cm precipitation/year) water levels were as low as 100 cm below the surface at some sites. Depth of the water tables was related not only to precipitation, but also presumably to ground water flow, and percent and type of cover (and thus, to total transpiration), as well as to soil properties, microtopography, and other watershed characteristics. Cedar growth rates are influenced by the water regime at individual sites, but no general relationship between them is discernible (Golet and Lowry 1987).

4.2 WATER CHEMISTRY

The water of Atlantic white cedar wetlands that are ombrotrophic (dependent on precipitation for water and minerals, as in many glacial kettles) is generally deficient in ions, has low specific conductance, and is low in pH (Laderman 1980; Golet and Lowry 1987)(Table 3); cedar stands that grow in stream-side or stream-fed swamps (as in the Pinelands [Schneider and Ehrenfeld 1987]; Florida [Clewell and Ward 1987]; and Mississippi [Eleuterius and Jones 1972]) or are subject to significant lateral flow (as in the Great Dismal [Bandle and Day 1985; USFWS 1986b]), are more minerotrophic (i.e., their water is enriched by mineral soils through which it passes) and often have a more neutral pH (Table 4). The chemical composition and pH of minerotrophic wetland water is closely tied to the chemistry of the rock strata and the nature of the vegetation in the region through which the source water flows (Gorham 1987).

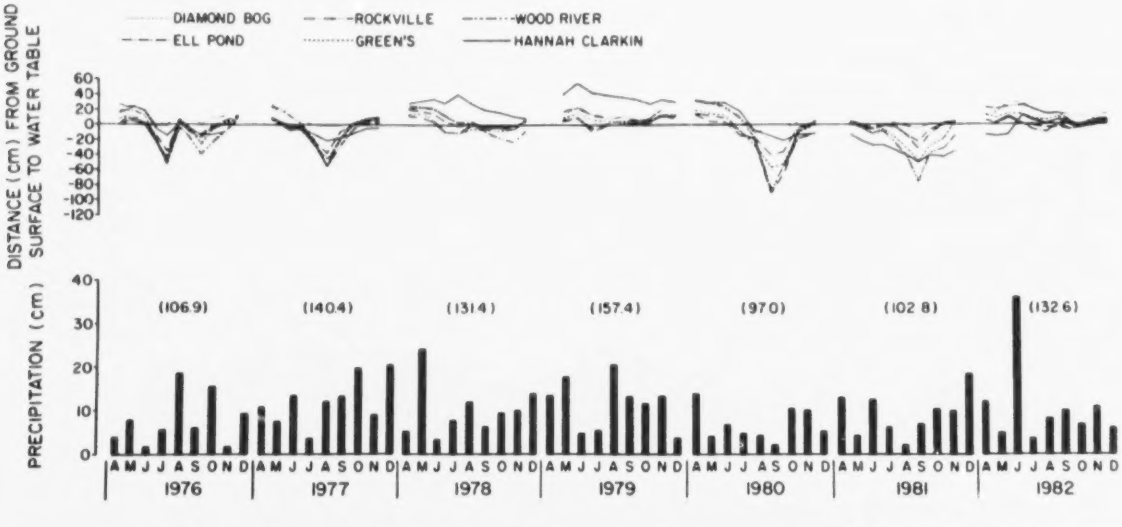

Figure 21. Water levels in six Rhode Island Cedar swamps over a seven year period. Monthly precipitation is plotted for the period of sampling; annual precipitation values are shown in parentheses (from Golet and Lowry 1987).

Table 3. Physical characteristics of six Rhode Island cedar swamps. From Golet and Lowry (1987).

Study area	Surficial geology	Site type[a]	Peat thickness	pH[b]	Specific conductance[b] (μmhos/cm^2)
Diamond Bog	stratified drift	bottomland–isolated	7.0	4.98	70
Ell Pond	till & bedrock	upland–lakeside	4.0	3.96	86
Green's Swamp	stratified drift	bottomland–isolated	4.0	3.84	148
Hannah Clarkin	till & strat. drift	upland–lakeside	4.0	4.20	119
Rockville	till & strat. drift	upland–isolated	2.2	3.82	112
Wood River	stratified drift	bottomland–isolated	6.0	4.26	220

[a] After Golet and Larson (1974). [b] Values are for ground water.

Table 4. Water chemistry of cedar wetlands in the Pinelands of southern New Jersey. Yearly mean of the ground water and surface water values at undisturbed sites in Lebanon State Forest (Protected) compared with values at severely impacted Pinelands sites subject to direct storm-sewer outfall from residential areas (Disturbed) (data from Schneider and Ehrenfeld 1987).

	Ground water		Surface water	
	Protected	Disturbed	Protected	Disturbed
	(n = 4)	(n = 5)	(n = 4)	(n = 5)
Temperature, °C	11.71± 0.38	12.61± 0.43	11.95± 0.66	12.36± 0.61
Diss. O_2, mg/L	2.55± 0.16	2.58± 0.14	4.36± 0.23	3.20± 0.17
Cl^-, mg/L	4.69± 0.19	15.24± 1.00	4.50± 0.23	12.81± 0.85
o-PO_4, μg/L	7.62± 1.54	43.57± 7.66	10.34± 2.41	34.38± 5.82
NH_3, μg/L	44.44± 9.66	491.75± 28.64	2.67± 1.84	188.82± 27.47
pH	2.78	4.45	2.54	3.62

4.3 SOILS

Atlantic white cedars grow primarily on organic soils (Histosols commonly termed "peat" or "muck") over a sand or sand/gravel base. In a few riverside stands in Florida and Mississippi, cedars grow on exposed sandbars extending into the channel (Figure 18); in an unusual situation in Georgia, they grow on sandy terraces. Water usually saturates these soils for long periods of the growing season, except where they are artificially drained. Histosols contain over 20% (by weight) organic matter if no clay is present, and over 30% organic matter if 50% clay is present in the upper 40 cm of the profile (Leighty and Buol 1983) (Cowardin et al. 1979:44-45 lists slightly different criteria). Figure 22 depicts a generalized profile through the substrate of a bog formerly dominated by cedar.

Histosols are classified in three major groups, based on their degree of decomposition. Fibrists are slightly decomposed, and hence the most fibrous; Saprists are greatly decomposed, with the least identifiable structure; and Hemists are intermediate in decomposition. In states south of Virginia, where decomposition is more rapid than in the north, most cedars are on Sapric soils, with a few on Hemists.

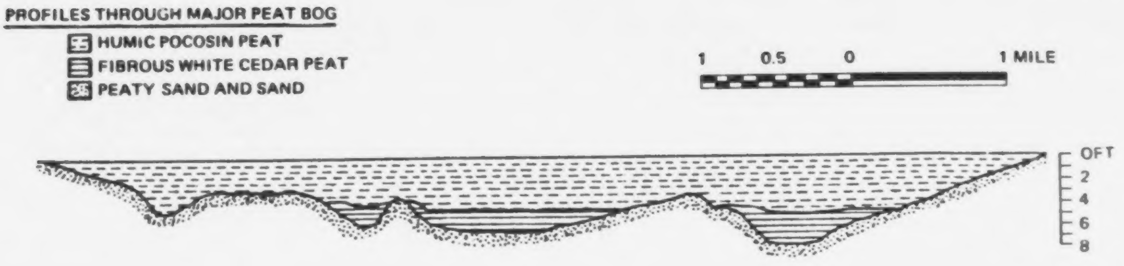

Figure 22. Substrate cross section through a pocosin formerly dominated by Atlantic white cedar (Croatan National Forest, North Carolina) (modified from Otte 1981).

The soil temperature regimes in which cedars grow are Frigid (Maine); Mesic (New Hampshire to Delaware and Maryland); and Thermic (Virginia to Florida and Mississippi).

Appendix C lists the criteria of the USDA Soil Conservation Service for hydric soils and for distinguishing organic from mineral soils. A complete list of hydric soils in "Hydric Soils of the United States" (USDA CS 1985a) includes information on the temperature regime; drainage class; depth and months of high water table; and frequency, duration, and months of flooding. Soil unit maps suitable for field work are prepared at the county level and may be obtained from state Agricultural Experiment Stations, local offices of the Soil Conservation Service, the Extension Service, and Soil and Water Conservation Districts.

Cedar histosols are high in organic content, cation exchange capacity, water holding capacity, and water content per unit volume, and low in ash content, bulk density, hydraulic conductivity, and available nutrients. Cedar peat is a rich red-brown. Aspects of the relevant characteristics of organic soils are discussed by Gorham (1987); Hemond et al. (1987); Ingram and Otte (1981); Leighty and Buol (1983); Otte (1981); Richardson et al. (1978).

4.4 PRODUCTION AND DECOMPOSITION

Day (1987) reviewed all research until 1984 on organic production and decay in Atlantic white cedar wetlands. This work was done primarily by Day and his colleagues (e.g., Dabel and Day 1977; Day 1982; Gomez and Day 1982) on a mixed *Chamaecyparis*/red maple/black gum site in the Virginia section of the Great Dismal Swamp.

The total aboveground biomass, fine root biomass, and aboveground net primary productivity for the four different Dismal Swamp forest communities measured all exhibited intermediate values for swamps in general (for comparative data, see Day, unpubl.). The annual foliage turnover (litterfall/biomass) for *Chamaecyparis* is 35%, a typical conifer value. The relatively large litter mass, slow decomposition rate of both cedar needles and total litter, and high concentration of tannins (4.19%) and lignins (19.94%) in cedar foliage correlate well with the observed accumulation of peat in cedar wetlands (Day 1987 and unpubl.) (Both lignins and tannins are believed to inhibit decay [Melillo et al. 1982; Cameron and LaPoint 1978].)

4.5 SOIL AND PLANT TISSUE CHEMISTRY

Whigham and Richardson (1988), in a recent study of the chemistry of a minerotrophic Maryland cedar wetland bordering a tidal creek, found cedar leaf tissue to be significantly higher in Ca, Al, Pb and Sr - and poorer in N and P - than other plants associated with it (Table 5). These differences indicate differential uptake and exclusion mechanisms in *Chamaecyparis* metabolism. Whigham and Richardson (1988) and Bandle and Day (1985) found that soil of cedar-dominated wetlands has higher Ca, Mg, Al, and Fe levels, and lower P content than surrounding wetlands; Whigham and Richardson observed that Atlantic white cedar sites are P, K, and possibly N limited.

Richardson (1985) showed that in acid wetland soils, available P levels are apparently controlled by extractable Al and Fe. The suite of cations thus far found in cedar soils is consonant with this view (Whigham and Richardson 1988).

Table 5. Mean August tissue nutrient concentrations of plant species in Maryland Coastal Plain wetlands. Atlantic white cedar site (n = 48) compared to means (±1 standard error) of species at five non-cedar sites (n = 175). Data from Whigham and Richardson (1988) and Whigham, pers. comm.

Nutrient	Atlantic white cedar		Other sites	
%N	1.61	±0.07	1.54	±0.04
%P	0.09	±0.01	0.12	±0.01
%K	1.18	±0.08	1.06	±0.04
%Ca	0.83	±0.05	0.70	±0.02
%Mg	0.43	±0.04	0.27	±0.01
%S	0.18	±0.01	0.17	±0.01
Mn µg/g	432	±36	281	±15.5
Fe µg/g	336	±38	265	±26.2
Cu µg/g	6.7	±0.4	6.5	±0.19
B µg/g	40.7	±3.0	35.3	±1.1
Al µg/g	174	±16	102	±4.9
Zn µg/g	53.5	±5.9	48.4	±3.5
Sr µg/g	59.8	±6.2	30.7	±1.6
Pb µg/g	17.8	±2.9	7.3	±0.3
Si µg/g	390	±18	342	±10.8

4.6 INTERACTIONS; RESEARCH NEEDED

Other factors not yet measured in cedar wetlands also probably play roles in the soil and water chemistry (Figure 23). The active cation exchange and adsorption capacity of peat (e.g., Gorham 1987), macromolecular aggregates, and *Sphagnum* mosses (e.g., Clymo 1963) appear to combine with selective ionic uptake by *Chamaecyparis* itself to control the water's nutrient content.

Measurement of all physical components of cedar wetlands will be useful in clarifying the functions that control life in an unusual environment. So little data have been accumulated that virtually every observation would be of both theoretical interest and of utility in management. There are great differences between sites; until more is known, it is inappropriate to extrapolate information from one cedar site to any others.

The scant research on the chemical composition of soils and vegetation of Atlantic white cedar wetlands has not yet produced a clear picture of cause and effect. This is probably due to the intrinsic complexity of relationships which are further obscured by the differing hydrogeological, lithological, biotic, and anthropogenic components of the sites examined.

Cedar wetland soil chemistry appears to differ greatly from its water chemistry. This may provide a clue to the depauperate chemical contents of cedar waters. The soil's active ion exchange, and adsorption processes that remove cations from the water may be part of the mechanism for the accumulation of minerals in *Chamaecyparis* soil and leaves.

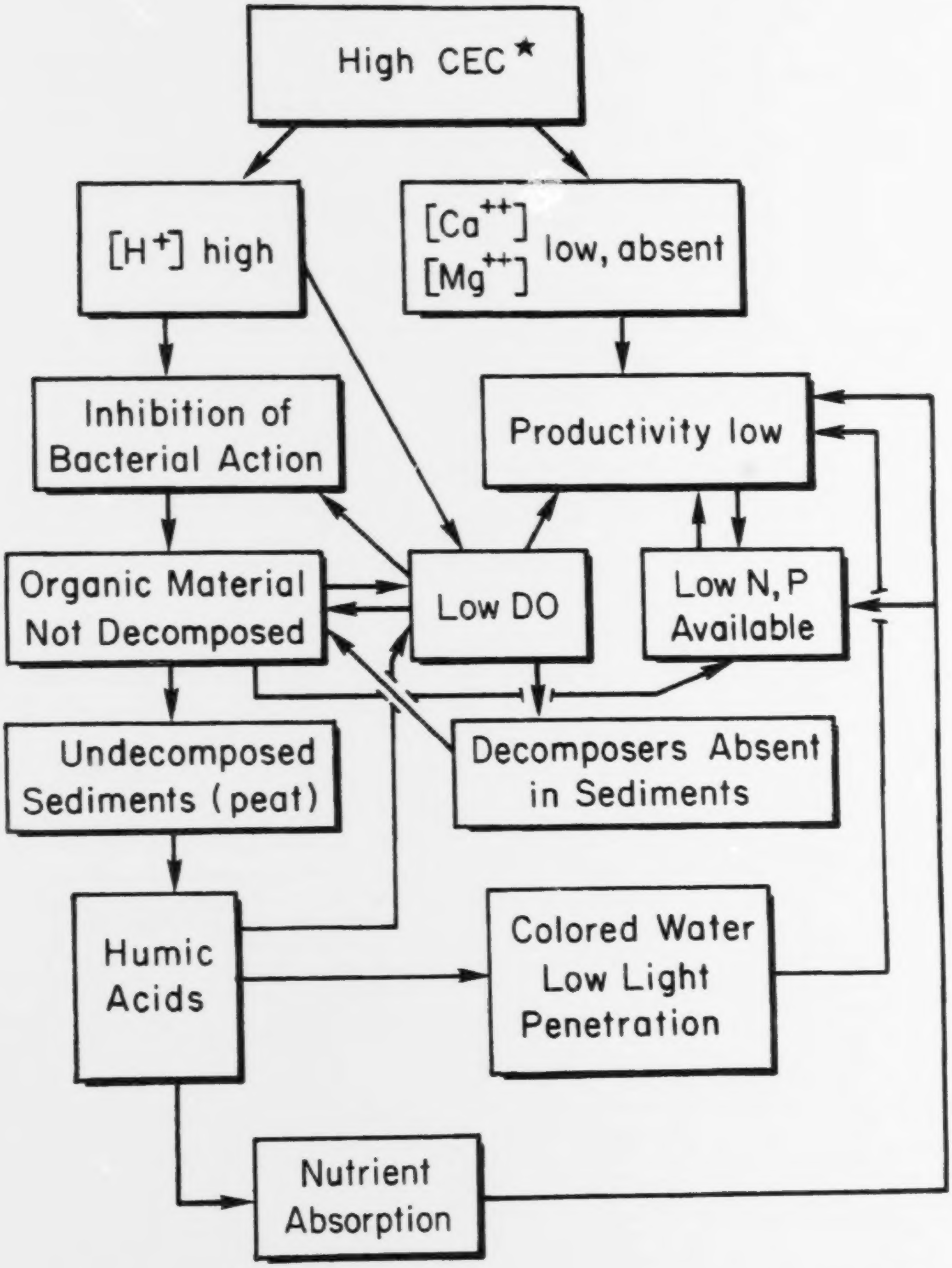
High CEC*
[H+] high
[Ca++] [Mg++] low, absent
Inhibition of Bacterial Action
Productivity low
Organic Material Not Decomposed
Low DO
Low N, P Available
Undecomposed Sediments (peat)
Decomposers Absent in Sediments
Humic Acids
Colored Water Low Light Penetration
Nutrient Absorption

Figure 23. Cedar wetland dynamics. Flow diagram indicates proposed interrelationships of physical, chemical and biological properties of Atlantic white cedar wetland waters (modified from Laderman 1980).

- CHAPTER 5 -

BIOLOGICAL COMPONENTS OF ATLANTIC WHITE CEDAR WETLANDS

5.1 ADAPTATIONS TO THE WETLAND ENVIRONMENT

Plant species growing with the Atlantic white cedar manage to thrive in a waterlogged environment with a varying hydroperiod, and generally acidic, nutrient-poor and often anaerobic soil and water. Major physical and physiologic adaptations to this suite of extreme conditions are a hallmark of the biota of the Atlantic white cedar community, but no quantitative work has been published on the subject. Waterlogging and its effects have been examined in bottomland hardwoods (Wharton et al. 1982); physiological adaptation of cells to the acidic milieu is discussed by Levandowsky (1987). Both works include a review of the pertinent literature.

5.2 FLORA

5.2.1 Diversity and Distribution of Associated Species

A relatively accurate picture of cedar wetland biota may be given by consideration of a combination of the most constant species (those most frequently co-occurring with Atlantic white cedar); the total species richness (number of species); and those few that are considered rare, endangered, or of other special regional concern. Plants that frequently co-occur are termed "constant companions" or "constant species" (Braun-Blanquet 1932; Braun-Blanquet and Pavillard 1930).

"Frequency" and "constancy" as used here refer only to the presence of a species in cedar-dominated assemblages and not to abundance of individuals or percent cover. Scientific and common names of all the reported associated vascular flora are recorded in Appendix A.

The vertical structure and vegetational composition of cedar wetlands vary with the age of the stand, the history of natural and anthropogenic disturbance, latitude, altitude, the hydrological regime, geomorphology, and microtopography. In some areas (e.g., New York's Long Island, New Jersey's Hackensack Meadows) many sites are so disturbed that species defined as constant companions of cedars decades ago are now no longer found with cedars, or are themselves near extirpation (see Chapter 2).

5.2.2 Constant Companions

Canopy co-dominants. A monospecific, dense, mature, even-aged stand may have a sparse to nonexistent subcanopy, shrub, herb, or reproduction layer, except at breaks in the canopy, and at the edges of the stand (by definition, no other tree occupies the canopy). In mixed stands throughout the cedar's range, the most frequently encountered trees are red maple and black gum.

Additionally, in the northern states, gray birch (*Betula populifolia*), black spruce, white pine, and hemlock are most widely distributed. In the middle of the range, sweet bay and a series of oaks (*Quercus)* and pines (*Pinus*) supplant most northern species. Further south, bay (*Gordonia lasianthus*, *Persea borbonia*, *P. palustris*) and cypress are also frequent canopy or subcanopy associates.

Shrub layer. Relatively open-canopy cedar stands generally have a well-developed shrub layer. More cedar-associated shrubs are in the heath family (Ericaceae) than in any other. The most widely distributed shrubs (including woody vines) associated with Atlantic white cedar are red chokecherry (*Aronia arbutifolia*), sweet pepperbush, bitter gallberry (*Ilex glabra*), fetterbush (*Leucothoe racemosa*), swamp honeysuckle, poison ivy (*Toxicodendron radicans*), poison sumac (*T. vernix*), and highbush blueberry.

Herbaceous layer. The most abundant herbaceous cover is found with cedar on bog mats and as a temporary feature shortly after disturbance that either eliminates the shrub layer or opens the canopy.

Where there is open water, submerged and emergent aquatics may be present. A continuous carpet of sphagnum mosses (*Sphagnum* spp.) is often seen wherever there is adequate light.

The most widely distributed cedar-associated herbs are: sedges (*Carex* spp.), round-leaved sundew (*Drosera rotundifolia*), partridge-berry (*Mitchella repens*), cinnamon fern, and royal fern (*O. regalis*). The complexity of distribution patterns and the large numbers of species preclude a simple distribution summary of the shrub and herbaceous layers. The complete geographic distribution of each species is presented in Appendix A. The most frequently encountered associated species are illustrated in Figure 24a, b, & c.

5.2.3 Species of Special Concern

Table 6 is an interim list of 89 cedar-associated species and subtaxa (5 trees, 26 shrubs, and 58 herbs) considered as regionally rare, threatened, or endangered. A few plants have recently been removed from some lists of special concern as populations increase or are discovered. Others have been locally extirpated. Individual naturalists, staffs of the Great Dismal Wildlife Refuge and the New Jersey Pinelands Commission, the Nature Conservancy, and state Natural Heritage Programs monitor and update these rosters. Further information is presented in Chapter 2 and Appendix A.

5.3 FAUNA

Information on animals and associated values is far more limited and spotty than on plants, reflecting the paucity of research in this area.

5.3.1 Wildlife Values

Habitat. A cedar forest managed for maximum wildlife habitat will contain a diverse mixture of old growth, mature, intermediate "pole", and regeneration areas (USFWS 1986b). Maximum variation in vertical stratification is of particular significance to avifauna (Anderson 1979). The cedar wetlands can be considered as ecological islands. Large, connected natural areas are of greatest value in promoting wildlife species diversity because there are more species per unit area than in separated islands, and there are fewer species lost due to genetic drift (e.g., MacArthur and Wilson 1967; Pianka 1974). Large blocks of unbroken territory are important for non-game bird species that nest on or near the ground or in open areas, or for species that are obligate forest-interior inhabitants, migrate long distances, or are shy of humans (Robbins 1979).

Excellent cover for deer, rabbits, and birds is provided by *C. thyoides* thickets (Korstian and Brush 1931). In the Northeast, a preferred winter browse for white-tailed deer (*Odocoileus virginianus*) is white cedar foliage and twigs (Little et al. 1958). Cottontail rabbit (*Sylvilagus floridanus*) and meadow mouse (*Microtus pennsylvanicus*) feed on cedar seedlings (Little 1950). In the Great Dismal, black bear feed on blueberry (*Vaccinium corymbosum*) and blackberry (*Rubus* sp.) growing in recently-cut cedar stands (Meanley 1973). Ward and Clewell (unpubl.) reported bear marker trees with huge jagged strips of hanging bark in Florida cedar wetlands. Wildlife, including bear, beaver, otter, and deer, is abundant in high-altitude New Jersey cedar wilderness areas (W. Foley, pers. comm.).

5.3.2 Birds

The only published quantitative reports on animal reproduction in cedar wetlands concern avifauna (Flaccus [1951] and Miller et al. [1987] for New Hampshire; NJPC [1980] for southern New Jersey; and Terwilliger [1987] for the Great Dismal Swamp).

Miller et al. (1987) counted 13 species of breeding birds at an average density of 145 breeding pairs per 40.5 ha in one New Hampshire swamp (Table 7). The same area had supported 23 breeding pairs in 1951 at a density of 159 pairs per 40.5 ha (Flaccus 1951).

Cedar stands in the Great Dismal National Wildlife Refuge supported the greatest bird density in coniferous forests censused in the eastern United States in 1981 (Terwilliger 1987). These stands held nearly twice as many birds per unit area as a surrounding maple-gum forest (Table 8). Seven species breed in cedar stands and not in maple-gum. Up to 23 breeding species and 95 individuals were counted in single 7-ha stands in one year's tally (Table 8).

Parulid warblers are the dominant avifauna in Great Dismal cedar stands; prairie, prothonotory, hooded and worm-eating warblers, ovenbirds, and yellowthroats comprised about three-fourths of the breeding birds found. Prairie and worm-eating warblers appear to be particularly dependent on the Great Dismal cedars. An "over-mature" stand, one with most trees over 100 years old, was particularly well populated. There are distinct species associations along vertical and temporal gradients, i.e., different-aged trees and stands support different bird species at various heights in and under the canopy in different seasons (Terwilliger 1987).

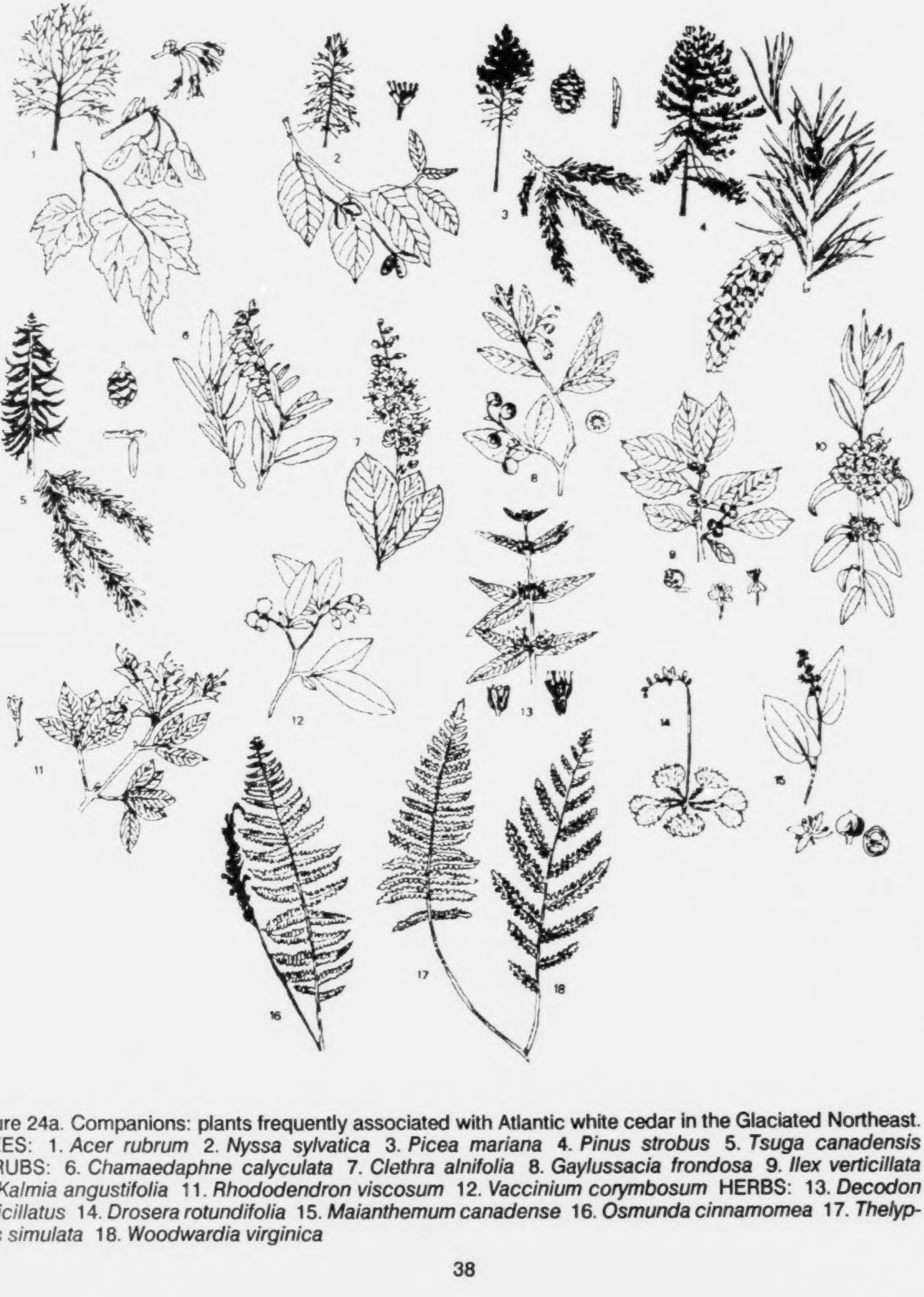

Figure 24a. Companions: plants frequently associated with Atlantic white cedar in the Glaciated Northeast. TREES: 1. *Acer rubrum* 2. *Nyssa sylvatica* 3. *Picea mariana* 4. *Pinus strobus* 5. *Tsuga canadensis* SHRUBS: 6. *Chamaedaphne calyculata* 7. *Clethra alnifolia* 8. *Gaylussacia frondosa* 9. *Ilex verticillata* 10. *Kalmia angustifolia* 11. *Rhododendron viscosum* 12. *Vaccinium corymbosum* HERBS: 13. *Decodon verticillatus* 14. *Drosera rotundifolia* 15. *Maianthemum canadense* 16. *Osmunda cinnamomea* 17. *Thelypteris simulata* 18. *Woodwardia virginica*

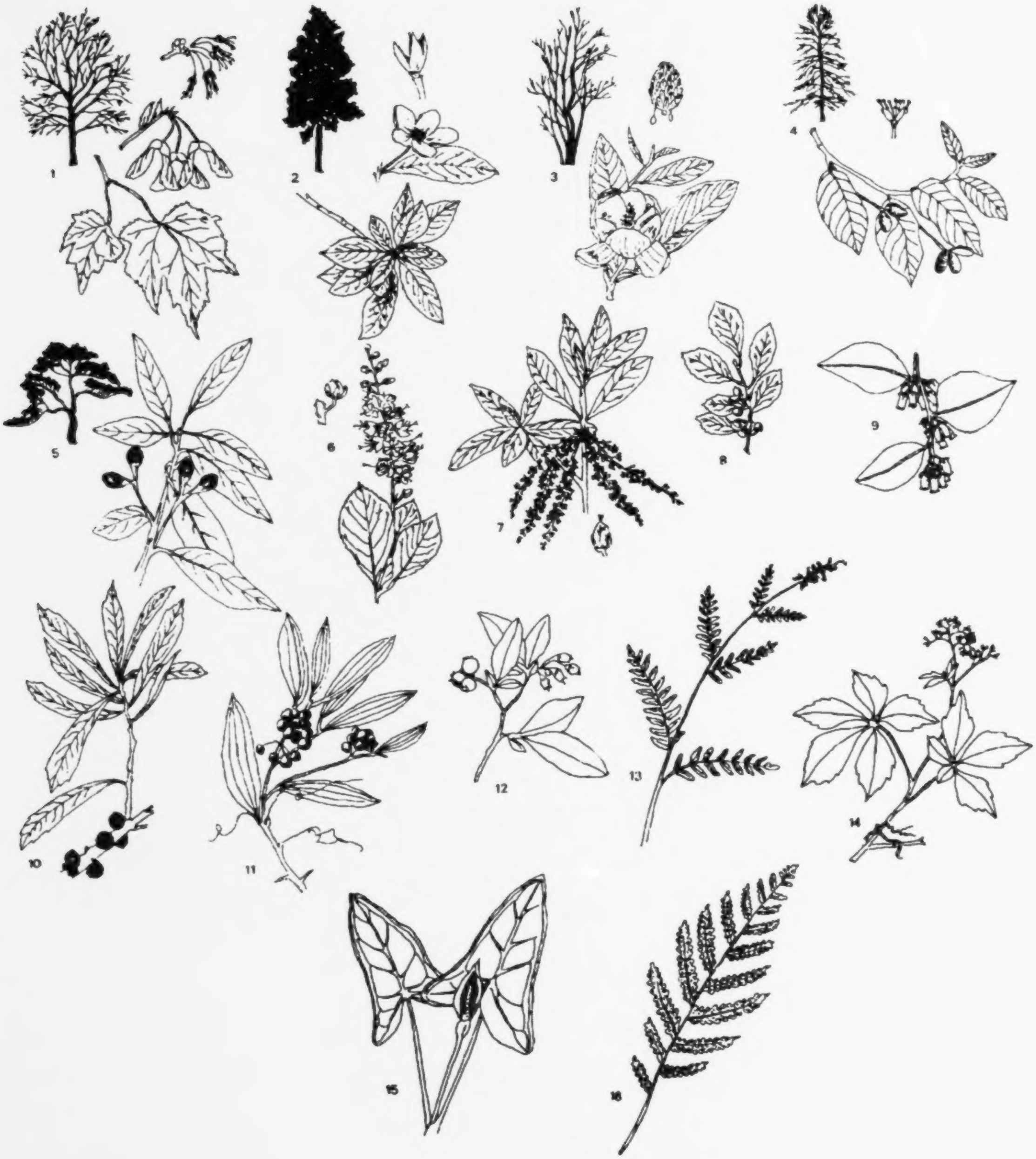

Figure 24b. Companions: plants frequently associated with Atlantic white cedar in Virginia and the Carolinas. TREES: 1. *Acer rubrum* 2. *Gordonia lasianthus* 3. *Magnolia virginiana* 4. *Nyssa sylvatica* var. *biflora* 5. *Persea borbonia*. SHRUBS: 6. *Clethra alnifolia* 7. *Cyrilla racemiflora* 8. *Ilex coriacea* 9. *Lyonia lucida* 10. *Myrica cerifera* 11. *Smilax laurifolia* 12. *Vaccinium corymbosum* HERBS: 13. *Osmunda regalis* 14. *Parthenocissus quinquefolia* 15. *Peltandra virginica* 16. *Woodwardia virginica*

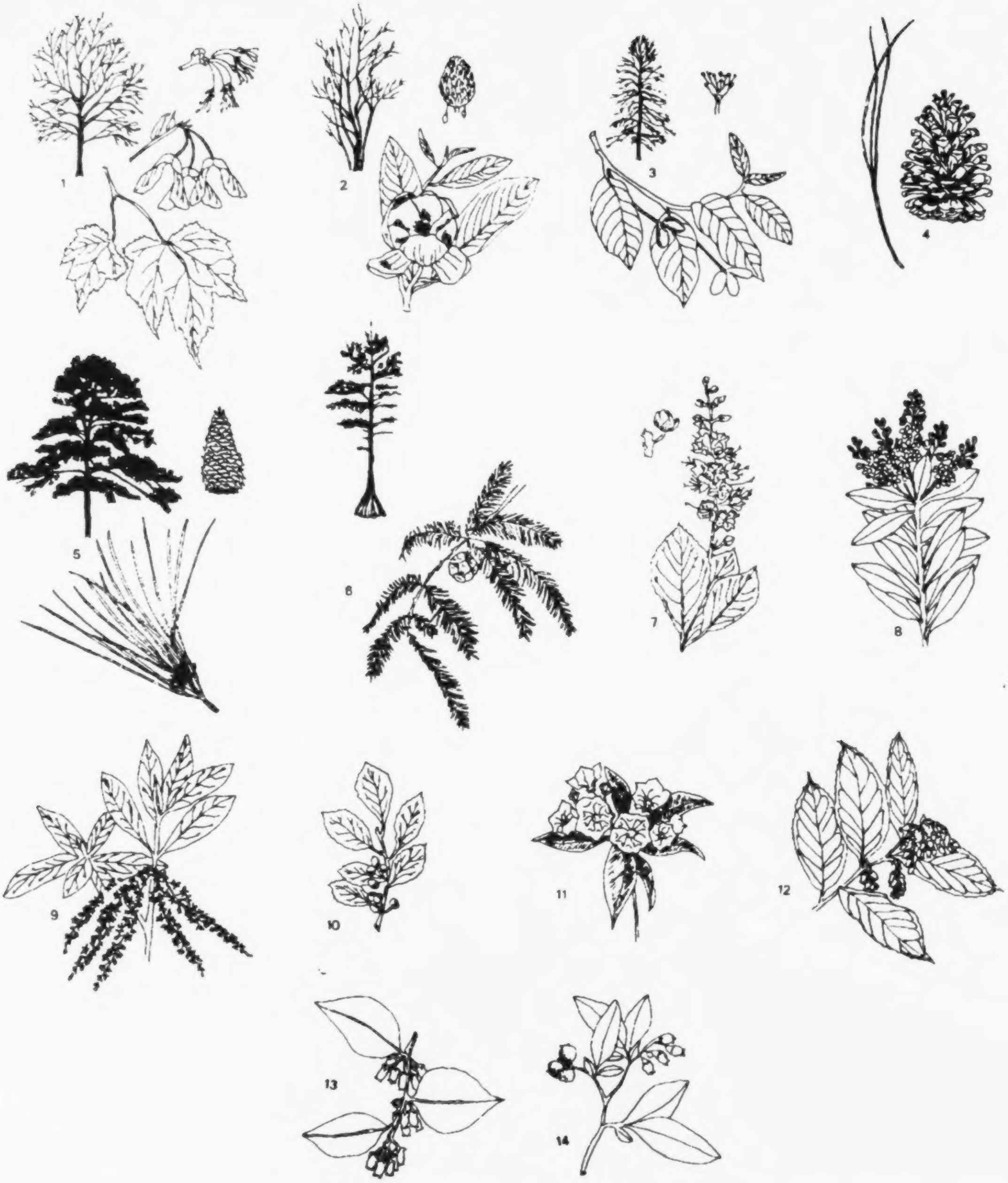

Figure 24c. Companions: Plants frequently associated with Atlantic white cedar in the Southeast. TREES: 1 *Acer rubrum* 2. *Magnolia virginiana* 3. *Nyssa sylvatica* var. *biflora* 4. *Pinus elliotti* 5. *Pinus taeda* 6. *Taxodium distichum* SHRUBS: 7. *Clethra alnifolia* 8. *Cliftonia monophylla* 9. *Cyrilla racemiflora* 10. *Ilex coriacea* 11. *Kalmia latifolia* 12. *Leucothoe axillaris* 13. *Lyonia lucida* 14. *Vaccinium corymbosum*

Table 6. Species of special concern: Flora. An interim list of species that are rare, threatened or endangered in one or more states where they co-occur with *Chamaecyparis thyoides*. See Appendix A for common names. Sources are listed by state, North to South. Stars (*) denote authorities who provided information and advice on the list for each state; their affiliations are listed in Appendix D.

Sources:
ME: *Barbara Vickery; Eastman 1978.
NH: *Frances Brackley; New Hampshire Natural Heritage Inventory (unpubl.); Storks and Crow [No date].
MA: *Bruce Sorrie and Henry Woolsey; Sorrie 1985.
RI: *Richard Enser; Church and Champlin 1978.
CT: *Kenneth Metzler; Connecticut Natural Diversity Database 1985.
NY: (Long Island): *John Turner; Mitchell et al. 1980.
NJ: *David Snyder; Snyder 1984.
MD, DE, VA: *Norman Dill and Arthur Tucker; Broome et al. 1979; Tucker et al. 1979; Porter 1979.
NC: *Julie Moore; Sutter et al. 1983.
SC: *John Nelson; *Douglas Rayner; Rayner et al. 1979.
FL: *Daniel Ward; Ward 1978.

Species	Location
TREES	
Larix laricina	RI
Magnolia virginiana	NY
Persea palustris	MD
Pinus serotina	MD
Salix floridana	FL
SHRUBS	
Alnus maritima	DE, MD
Andromeda glaucophylla	RI, NJ
Arceuthobium pusillum	RI, NJ
Callicarpa americana	MD
Gaultheria hispidula	RI, CT, NJ
Gaylussaccia dumosa v. *bigeloviana*[a]	RI
Gaylussaccia dumosa v. *hirtella*[a]	SC
Gaylussaccia mosieri	SC
Ilex laevigata	ME
Illicium parviflorum	FL
Kalmia cuneata	NC, SC
Kalmia angustifolia	DE
Kalmia latifolia	FL
Kalmia polifolia	RI
Nemopanthus mucronatus	RI
Pieris phillyreifolia	FL
Rhapidophyllum hystrix	FL
Rhododendron canadense	RI
Rhododendron chapmanii	FL
Rhododendron maximum	MA, CT
Smilax laurifolia	NJ
Smilax walterii	NJ, MD
Symplocos tinctoria	MD
Taxus floridana	FL
Vaccinium oxycoccos	NJ
Vaccinium sempervirens	SC
HERBS	
Arethusa bulbosa	DE, VA
Asclepias rubra	NJ
Calla palustris	RI
Carex collinsii	DE, MD
Chrysoma pauciflosculosa	SC
Cleistes divaricata	NJ
Corallorhiza trifida	CT
Cornus canadensis	RI
Cyprepedium acaule	SC
Drosera rotundifolia	DE, MD
Eleocharis equisetoides	DE, MD
Eleocharis robbinsii	NY, SC
Epigaea repens	DE
Eriocaulon compressum	VA
Eriocaulon parkeri	DE, MD
Eriocaulon septangulare	MD
Eriophorum tenellum	NJ
Eupatorium resinosum	NJ
Helonias bullata	NJ, DE, VA
Hudsonia ericoides	SC
Iris prismatica	DE, MD
Juncus caesariensis	NJ
Liparis loeselii	NJ
Listera australis	NJ
Listera cordata	MA
Lobelia canbyi	NJ
Lycopodium inundatum	RI
Lycopodium obscurum	SC
Myriophyllum humile	MD
Nymphoides cordata	NJ
Oxypolis rigidior v. *ambigua*	DE
Panicum hemitomon	NJ
Parnassia grandifolia	FL
Peltandra virginica	ME
Platanthera ciliaris	NJ
Potamogeton confervoides	ME, NJ
Psilocarya nitens	MD
Rhynchospora alba	VA, SC
Rhynchospora cephalantha	NJ
Rhynchospora glomerata	MD
Rhynchospora knieskernii	NJ, SC
Sarracenia purpurea ssp. *purpurea*	DE, MD
Schizaea pusilla	NJ
Scirpus etuberculatus x *s. subterminalis*	SC
Scirpus subterminalis	SC
Sclerolepis uniflora	NJ,MD
Solidago stricta	NJ
Solidago verna	SC
Thelypteris simulata	DE, MD, VA
Tofieldia racemosa	NJ, SC
Utricularia cornuta	RI
Utricularia fibrosa	MD
Utricularia purpurea	NJ, MD
Utricularia resupinata	NJ
Utricularia juncea	DE, MD

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[a] Only *G. dumosa* is recognized in NLSPN (1982) and the USFWS wetland Plant List (Reed 1986). The varieties *bigeloviana* and *hirtella* are recognized by local authorities.

Table 7. Comparison of bird species observed in a 5.87-ha Atlantic white cedar swamp study plot in Barrington, NH, in 1951 and 1981. Migrants and birds visiting but not nesting in the plot are classed as "seen in plot." Nomenclature follows the American Ornithologists' Union Committee on Classification and Nomenclature (1982). Data from Flaccus (1951) and Miller et al. (1987).

		Breeding pairs		Seen in plot	
Common name	Scientific name	1951	1984	1951	1984
Sharp-shinned hawk	*Accipiter striatus*			x	
Red-shouldered hawk	*Buteo lineatus*			x	
Ruffed grouse	*Bonasa umbellus*			x	
Black-billed cuckoo	*Coccyzus erythrophthalmus*			x	
Great horned owl	*Bubo virginianus*			x	
Barred owl	*Strix varia*			x	
Common flicker	*Colaptes auratus*			x	
Pileated woodpecker	*Dryocopus pileatus*			x	
Hairy woodpecker	*Picoides villosus*				x
Downy woodpecker	*Picoides pubescens*	1			
Great crested flycatcher	*Myiarchus crinitus*			x	
Eastern pewee	*Contopus virens*	1/2	1/2		
Blue jay	*Cyanocitta cristata*	1	2		
American crow	*Corvus brachyrhynchos*			x	
Black-capped chickadee	*Parus atricapillus*	1	2		
White-breasted nuthatch	*Sitta carolinensis*				x
Red-breasted nuthatch	*Sitta canadensis*			x	
Brown creeper	*Certhia familiaris*	1	1		
Gray catbird	*Dumetella carolinensis*		1		
American robin	*Turdus migratorius*				x
Wood thrush	*Hylocichla mustelina*				x
Hermit thrush	*Catharus guttatus*	1 1/2	1		
Veery	*Catharus fuscescens*	1	1		
Ruby-crowned kinglet	*Regulus calendula*			x	
Solitary vireo	*Vireo solitarius*	1			
Red-eyed vireo	*Vireo olivaceus*		2	x	
Black-and-white warbler	*Mniotilta varia*		2	x	
Magnolia warbler	*Dendroica magnolia*	2			
Yellow-rumped warbler	*Dendroica coronata*			x	
Black-throated blue warbler	*Dendroica caerulescens*	2			x
Black-throated green warbler	*Dendroica virens*	1			
Blackburnian warbler	*Dendroica fusca*				x
Chestnut-sided warbler	*Dendroica pensylvanica*			x	
Bay-breasted warbler	*Dendroica castanea*			x	
Ovenbird	*Seiurus aurocapillus*	3	1 1/2		
Northern waterthrush	*Seiurus noveboracensis*		1	x	
Common yellowthroat	*Geothlypis trichas*		1	x	
Wilson's warbler	*Wilsonia pusilla*			x	
Canada warbler	*Wilsonia canadensis*	5	5		
American redstart	*Setophaga ruticilla*				x
Scarlet tanager	*Piranga olivacea*	1/2			x
Rose-breasted grosbeak	*Pheucticus ludovicianus*	1/2			
Purple finch	*Carpodacus purpureus*	1			x
American goldfinch	*Carduelis tristis*			x	
Rufous-sided towhee	*Pipilo erythrophthalmus*				x
White-throated sparrow	*Zonotrichia albicollis*			x	x
Number of species		16	13	22	11
Number of pairs		23	21		
Density per 100 acres (40.5 ha)		158.6	144.8		

Table 8. Species and number of breeding birds observed on cedar and maple-gum forest study sites in the Great Dismal Swamp, based on the number of territorial birds, rounded to the nearest 0.5 territory. For marginal territories having less than 25% of the territory within the study site, a "+" was assigned. From Terwilliger (1987).

		Cedar Stands				Maple-gum Stand		
		Site 1		Site 2		Site 3		
Common Name	Scientific Name	'80	'81	'80	'81	'78	'79	'80
Red-shouldered hawk	*Buteo lineatus*	+	+			+		
Mourning dove	*Zenaida macroura*	2	+	+	+	1		1
Yellow-billed cuckoo	*Coccyzus americanus*					3	2	2
Barred owl	*Strix varia*					+		+
Pileated woodpecker	*Dryocopus pileatus*	1	1	+		+	+	+
Hairy woodpecker	*Picoides villosus*						+	+
Downy woodpecker	*Picoides pubescens*					+	2	2
Common flicker	*Colaptes auratus*			1			+	
Great crested flycatcher	*Myiorchus crinitus*	2	2	3	2	2	7	4
Eastern wood pewee	*Contopus virens*	+					4	3
Acadian flycatcher	*Empidonax virescens*	1	2		1			
Blue jay	*Cyanocitta cristata*	1	1	2	1			
Carolina chickadee	*Parus carolinensis*	3	2	4	3	3	1	3
Tufted titmouse	*Parus bicolor*	3	1	2	1			
Carolina wren	*Thryothorus ludovicianus*	+		1		4	4	3
Gray catbird	*Dumetella carolinensis*	1	1	3	2			
Wood thrush	*Hylocichla mustelina*	2	1	5	3	6	6	6
Blue-gray gnatcatcher	*Polioptila coerulea*					1		
Red-eyed vireo	*Vireo olivaceus*	3	3			3	4	3
White-eyed vireo	*Vireo griseus*	2	2.5					2
Prothonotary warbler	*Protonotaria citrea*	18	15	4	3	13	10	11
Pine warbler	*Dendroica pinus*					1		
Prairie warbler	*Dendroica discolor*	18	17	19	15			
Swainson's warbler	*Limnothlypis swainsonii*	1				+		
Worm-eating warbler	*Helmitheros vermivorus*	5	2	5	4			
Hooded warbler	*Wilsonia citrina*	13	10.5	12	12	5	6	5
Common yellowthroat	*Geothlypis trichas*	3	2.5	19	16	8	5	6
Louisiana waterthrush	*Seiurus motacilla*					5	5	4
Ovenbird	*Seiurus aurocapillus*	8	7	11	8	5	7	7
Cardinal	*Cardinalis cardinalis*	1	1					
Rufous-sided towhee	*Pipilo erythrophthalmus*	+	2	4	2	+		+
Chipping sparrow	*Spizella passerina*					+		
Summer tanager	*Piranga rubra*					+		
Total number of species		23	20	17	15	22	16	19
Total number of individuals		88	73.5	95	73	60	63	62
Density (per km$^{2)}$		1,256	1,035	1,369	1,042	593	623	613

Meanley (1979) emphasized the importance of cedar as food source and habitat for wintering birds; for example, he observed one Great Dismal stand containing 10,000 pine siskin feeding at once, the largest such gathering ever reported.

Cooper's hawk (*Accipiter cooperi*) (an endangered species in New Jersey), the red-shouldered hawk (*Buteo linelus*), and the barred owl (*Strix varia*) (listed as threatened in the State) inhabit Pinelands cedar swamps (New Jersey Pinelands Commission [NJPC] 1980). The NJPC estimates that 39 bird species, including 11 nesters, currently live in the Pinelands cedar wetlands. The threatened barred owl and the hooded warbler (*Wilsonia citrina*) (now uncommon to rare in New Jersey) have been recorded as breeding in these swamps (Leck 1984; McCormick 1970). The northern parula (*Parula americana*), designated as extirpated in New Jersey, may be reestablishing itself as a breeder in the Pinelands cedar swamps (NJPC 1980). The hooded warbler was once abundant in Cape May cedar wetlands (Stone 1894). The northern raven (*Corvus corax*) formerly nested in Jersey cedar swamps, but it has not been known to breed in the region since the turn of the century (Bull 1964).

Among the 19 bird species found nesting in Rhode Island cedar wetlands (R. Enser, pers. comm.) are 3 species that rarely nest in that state: the northern goshawk, winter wren, and white-throated sparrow (Table 9).

5.3.3 Insects

The larva of one butterfly reviewed by the USFWS for endangered status feeds exclusively on *C. thyoides* (Cryan 1985). Hessel's hairstreak (*Mitoura hesseli*), a member of the Family Lycaenidae which includes blues, coppers and hairstreaks, is an emerald-green butterfly which has been found in cedar swamps of Long Island, New York (Cryan 1985), Connecticut (Maier 1986), Delmarva (Dill et al., unpubl.), the Great Dismal Swamp, Virginia and North Carolina (Beck and Garnett 1983) and Dare County, North Carolina (see Section 7.4). Maier (in prep., with literature review) reported a Connecticut sighting for the federally endangered banded bog skimmer dragonfly (*Williamsonia lintneri*) (USFWS 1984b), whose few extant populations are in or near Atlantic white cedar swamps in New Jersey, New York, Rhode Island, Massachusetts, and New Hampshire.

Table 9. Birds breeding in Rhode Island wetlands. Data from R. Enser (pers. comm.).

wood duck
osprey
sharp-shinned hawk
cooper's hawk
northern goshawk[a]
red-shouldered hawk
barred owl
saw-whet owl
downy woodpecker
hairy woodpecker
northern flicker
american crow
black-capped chickadee
red-breasted nuthatch
winter wren[a]
solitary vireo
northern parula (very rare)
canada warbler
white-throated sparrow[a]

[a] Birds that rarely nest in Rhode Island.

5.3.4 Other Fauna

Information on animals other than birds in Atlantic white cedar wetlands is scant and is generally not quantitative beyond simple and incomplete census data. Mammals, reptiles, and amphibians are listed phylogenetically in Appendix B with both common and scientific names.

Rhode Island. In addition to the eight mammalian and seven herptile species that have been identified to date as occurring in Rhode Island cedar wetlands, it is suspected that the wood turtle and the southern bog lemming (rare in Rhode Island) would be found on persistent investigation (R. Enser, pers. comm.).

New Jersey Pinelands. Nineteen species of mammals are reported to be currently associated with cedar swamps in the Pine Barrens. The bobcat, black bear, and beaver have been extirpated from the region; beaver has been reintroduced there and may now be common in some parts of the Barrens. Fifteen species of fishes are considered characteristic of acid Pinelands streams. The ironcolor shiner is commonly seen in small channels in Atlantic white cedar swamps (NJPC 1980).

The New Jersey Pinelands Commission (1980) selected fourteen herptile species found in the region's cedar wetlands for intensive study because of their distribution patterns or declining populations. Among them are seven species classified by the New Jersey Division of Fish, Game, and Wildlife as endangered (the Pine Barrens treefrog, bog turtle, and timber rattlesnake); threatened (the northern pine snake and eastern mud salamander); or declining (the four-toed salamander and northern red salamander). The status of the remaining species of special concern has not yet been determined.

Great Dismal Swamp. The Refuge staff gathered qualitative information on 49 animal species currently found in the cedar wetlands of the Great Dismal. Vertical stratigraphy, percent cover, seasonal occurrence, and preferences for forest age class were recorded (USFWS 1986b). The list includes 32 bird species (with 26 nesting in cedar swamps, including 2 waterfowl), 10 mammals (all nesting), and 7 herptiles (5 known breeding).

5.4 RESEARCH NEEDS

Qualitative plant surveys, while still incomplete, are abundant; quantitative information is sparse and scattered. As many plants are at the extent of their ranges in cedar wetlands, or have a special affinity for such sites, multifactorial analysis of available data would help in assessing the factors that control the distribution of flora both locally and in the larger biogeographic realm. This could be of particular value in the protection of rare, endangered, or threatened species.

Prior to the introduction of new species, or the reintroduction of extirpated natives, it is necessary to census the extant community. Faunal surveys are essential as baseline information for environmental impact statements and for sensible judgment of the effects of any management technique of other potential impact on both plant and animal populations.

- CHAPTER 6 -

MANAGEMENT AND HARVEST

6.1 IMPACTS OF DISTURBANCE

We shall first consider the impacts of disturbance under many conditions in the natural forest to attempt to explore the interrelationship of the multiple factors that govern the ecosystem's functions. A better understanding of the cedar wetland's native state should provide a rational basis for its management.

6.1.1 Fire and Water

The major parameters of disturbance involve water (its depth and the duration of flooding or drought) and fire (its intensity and duration, which in turn depend on the velocity and direction of wind; water levels; available fuel, e.g., slash, brush, exposed dry peat; and other factors). Fire has both immediate and long-term impact. The destructiveness of a fire is inversely related to the amount of water present. For instance, at lower water, more peat burns. The deeper the peat burn, the lower the possibility that viable seed will remain in the forest floor, and the lower the possibility that a new cedar stand will develop. However, a light fire at high water tends to eliminate shrubs and brush, and favors cedar seedling germination and survival. For detailed discussion, see Little (1946, 1950, 1953, 1979); Little et al. (1948a,b); and Windisch (1987).

The relationship of Atlantic white cedar to fire and water appears paradoxical: cedar stands are destroyed by fire, but light fire clears competition from the substrate surface, permitting cedar reproduction. A very hot prolonged fire at low water burns off peat, which can result in more standing water. Cedar seedlings are drowned by flooding; mature trees are stressed by permanent inundation. However, flooding severe enough to kill undergrowth prepares a seedbed favorable to cedars, and high moisture content is essential for cedar reproduction and growth.

6.1.2 Other Factors

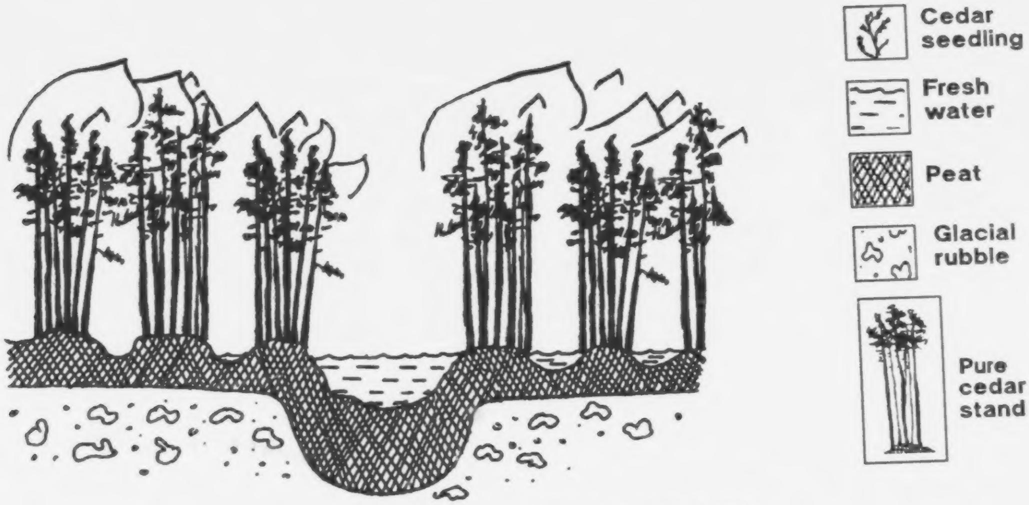
Other disturbances in the natural forest are caused by storms (windthrow, ice damage, salt spray, saline water incursion). Deer browse can destroy young stands; herbivory by mice and rabbits has less impact (Little 1958). The girdling and felling of cedars by beaver are of minor importance compared to the beavers' major hydrological alterations that destroy or create cedar habitat. Currently, by far the most significant influence on the creation and destruction of cedar wetlands by natural forces is the slow rise of sea level. The effects of the natural rise of sea level and of man-induced saline incursion are discussed in Sections 1.4 and 2.2.2 (Hackensack Meadowlands in northern New Jersey).

In each episode of disturbance, history is intrinsically a factor, as the cedar community at each site is adapted to a particular range of water, light, weather, etc., regimes. An abrupt change is, by itself, a stress factor. Flooding a dry site or drying a flooded site will shift the existing balance between species, whereas continuation of the same situation will leave species ratios unaltered.

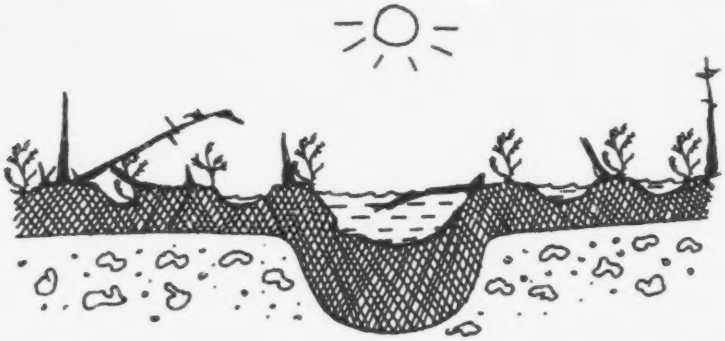
A series of sketches and flow diagrams illustrates some of these interactions (Figures 25 - 29).

6.1.3 Anthropogenic Influences

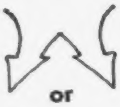
Suburban encroachment. Studies in the New Jersey Pinelands (Ehrenfeld 1983; Schneider and Ehrenfeld 1987) indicate that suburbanization eliminates the characteristic cedar-associated species and erodes water quality. Residential development is accompanied by an increase in species richness, with an initial increase in drier-site species followed by a large increase in non-indigenous species as native plants disappear. Regional water chemistry is strongly influenced by surface inflow of storm drainage carrying heavy sediment loads and by septic tank eutrophication. Water

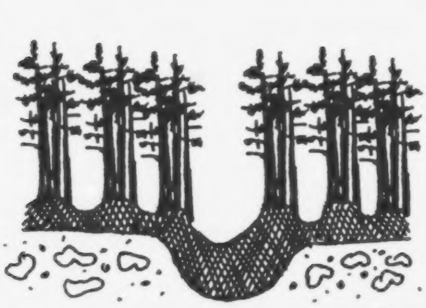


Fire burns cedar crowns killing the cedars. Shrubs and debris burn; most peat, and cedar seed within it, remains unburned.

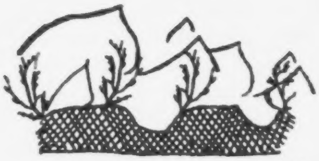


Next Growing Season
Light and warmth reach the forest floor. With no interfering shrubs or debris, seed stored in the upper layers of the peat germinates.



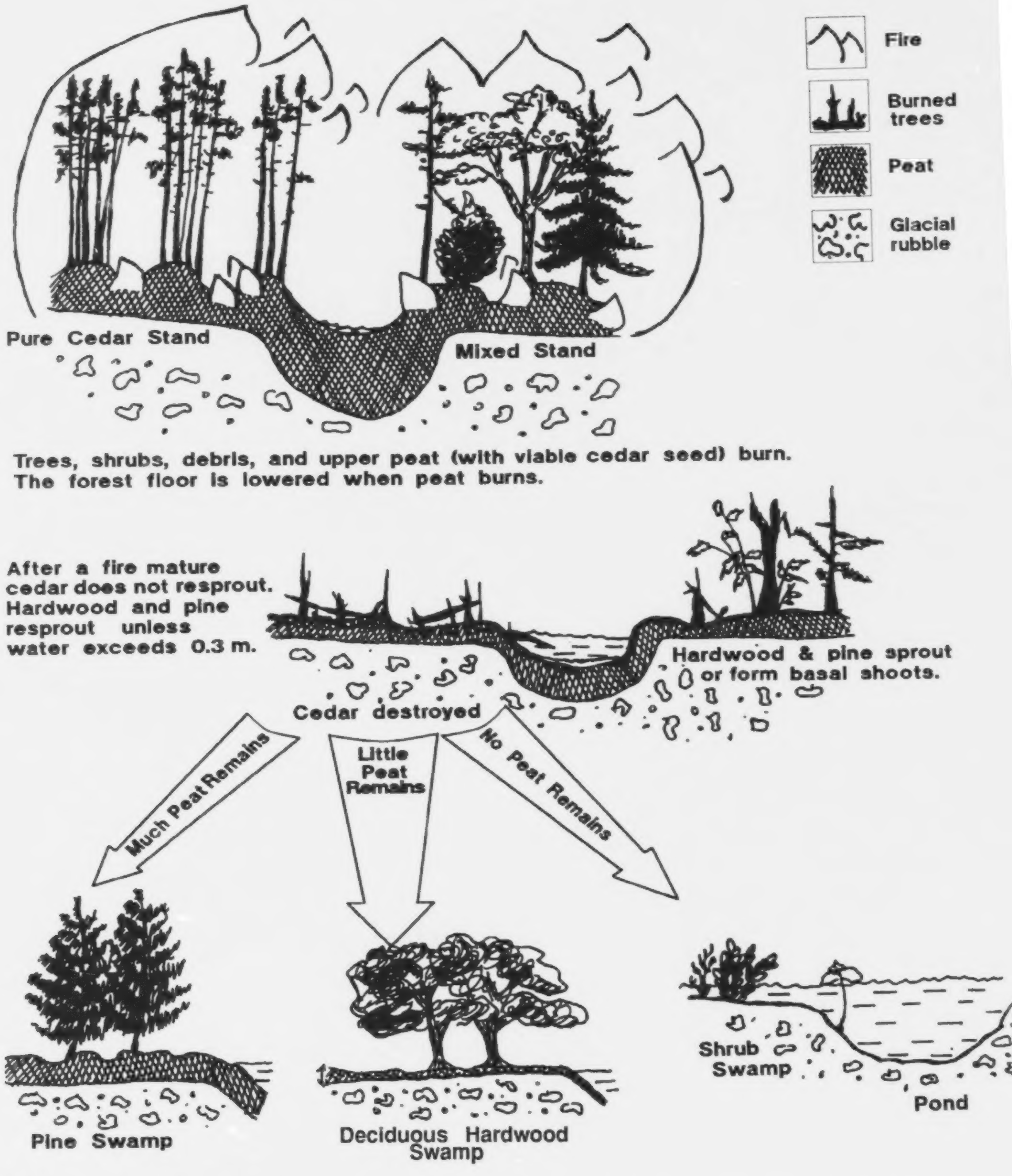


Even-aged Monotypic Cedar Forest



A second fire after germination generally destroys the entire crop. Cedar will not regenerate.

Figure 25. Effects of fire during high water in Atlantic white cedar wetlands.

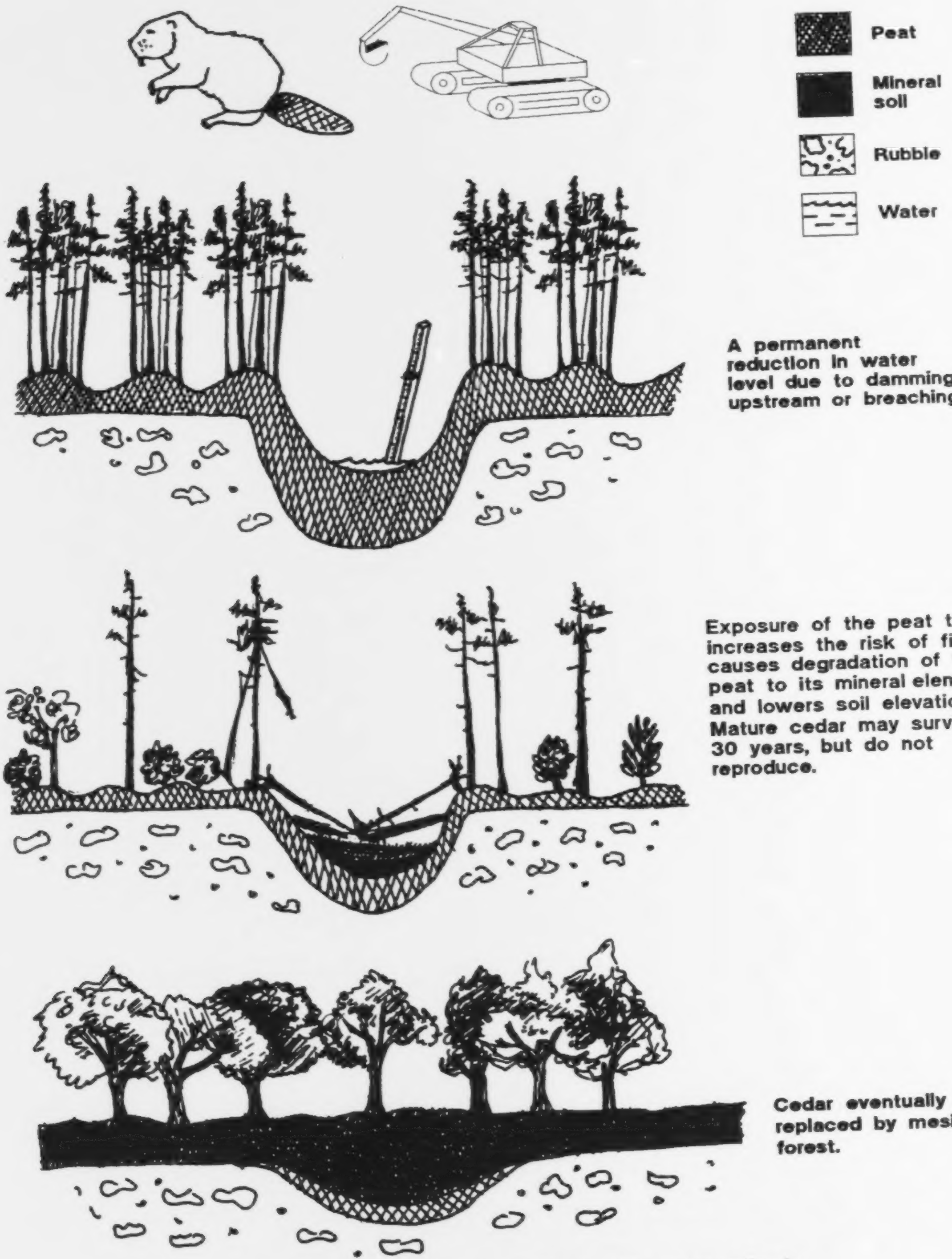


Trees, shrubs, debris, and upper peat (with viable cedar seed) burn. The forest floor is lowered when peat burns.

After a fire mature cedar does not resprout. Hardwood and pine resprout unless water exceeds 0.3 m.

After a low-water fire, deep peat favors pine; mineral soil favors hardwood. A lowered forest floor may support a bog pond or shrub swamp.

Figure 26. Effects of fire during low water in Atlantic white cedar wetlands.



A permanent reduction in water level due to damming upstream or breaching.

Exposure of the peat to air increases the risk of fire, causes degradation of the peat to its mineral elements, and lowers soil elevation. Mature cedar may survive 30 years, but do not reproduce.

Cedar eventually is replaced by mesic forest.

Figure 27. Effects of desiccation in Atlantic white cedar wetlands.

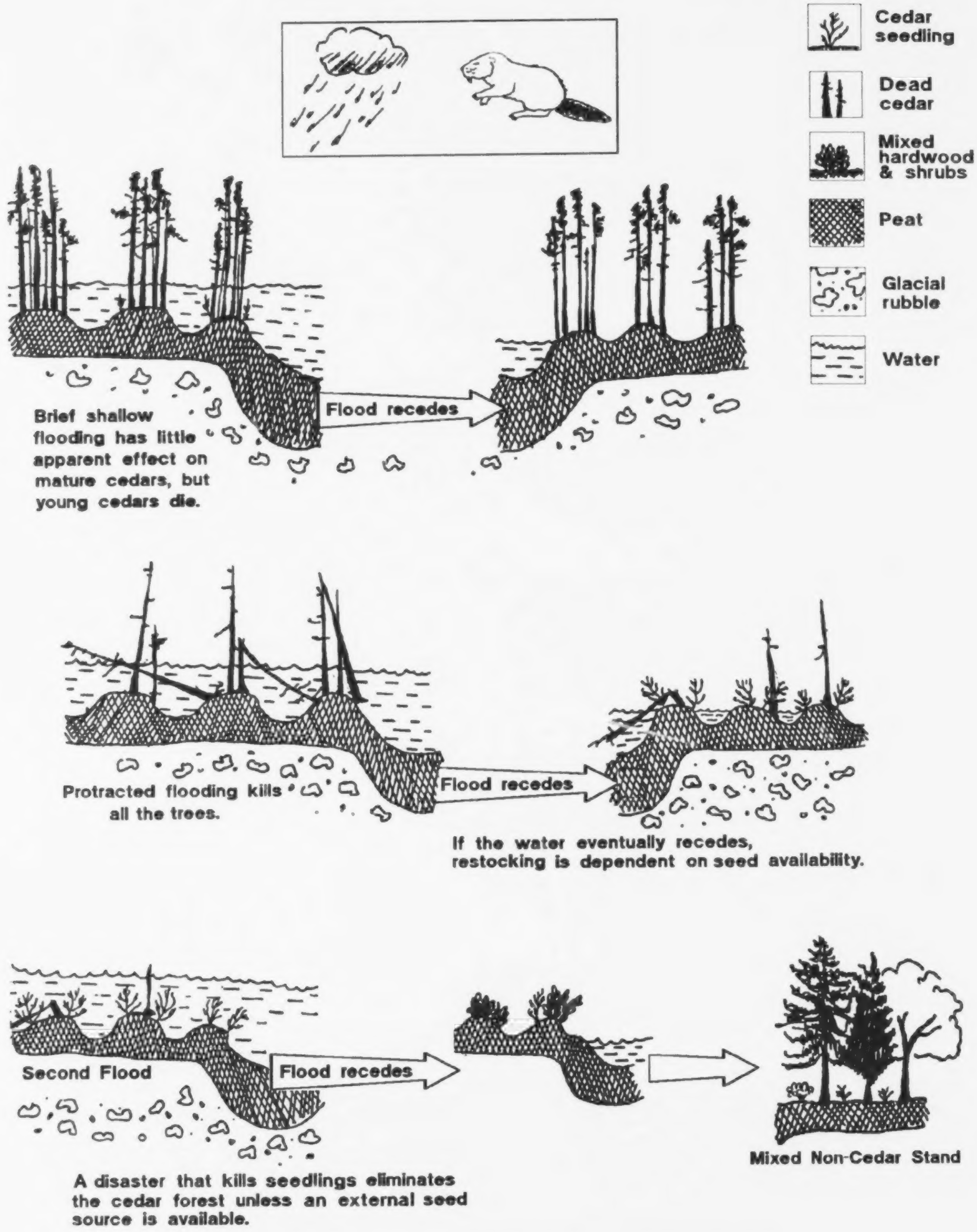

Cedar seedling
Dead cedar
Mixed hardwood & shrubs
Peat
Glacial rubble
Water
Brief shallow flooding has little apparent effect on mature cedars, but young cedars die.
Flood recedes
Protracted flooding kills all the trees.
Flood recedes
If the water eventually recedes, restocking is dependent on seed availability.
Second Flood
Flood recedes
A disaster that kills seedlings eliminates the cedar forest unless an external seed source is available.
Mixed Non-Cedar Stand

Figure 28. Effects of flooding in Atlantic white cedar wetlands.

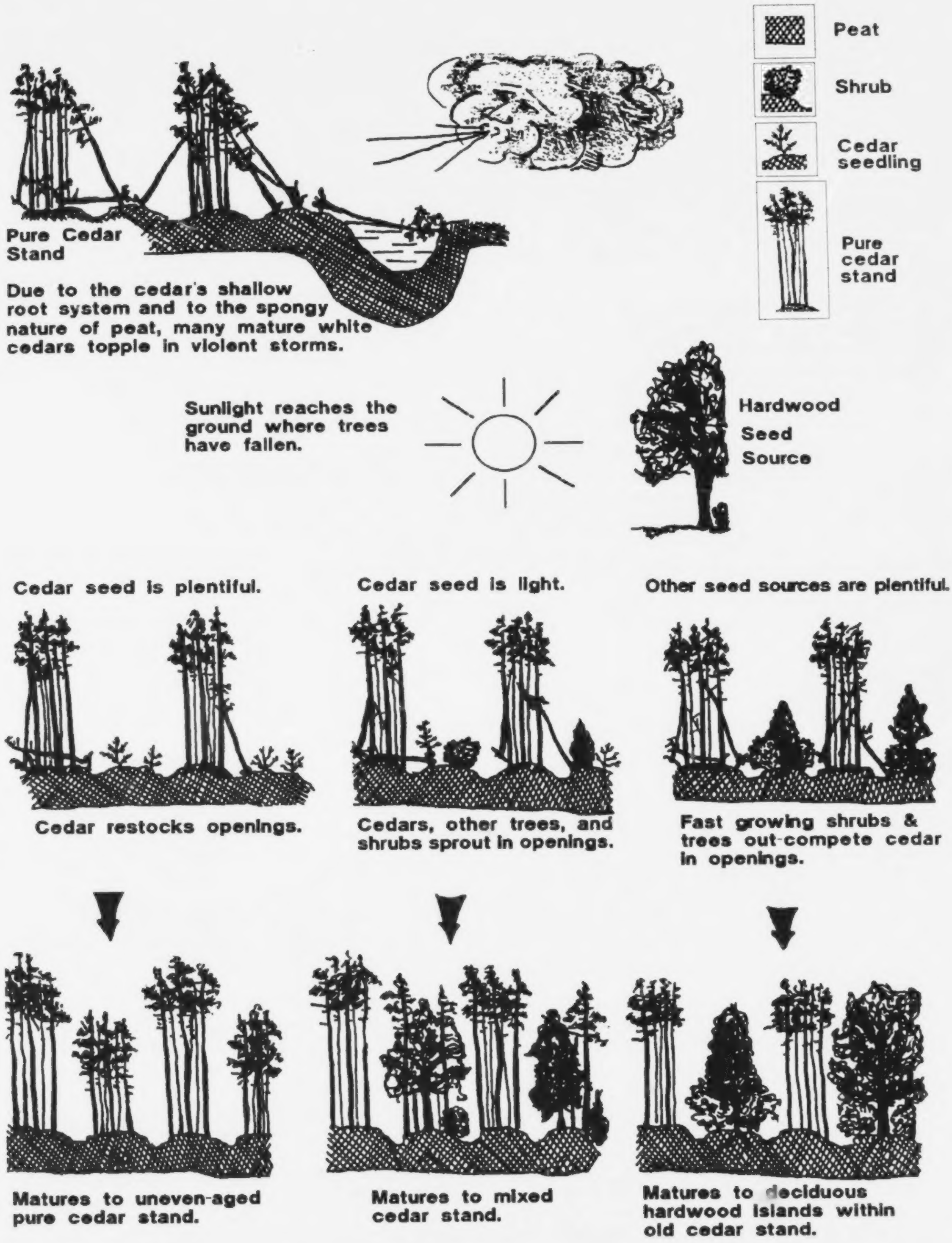

Peat
Shrub
Cedar seedling
Pure cedar stand
Pure Cedar Stand
Due to the cedar's shallow root system and to the spongy nature of peat, many mature white cedars topple in violent storms.
Sunlight reaches the ground where trees have fallen.
Hardwood Seed Source
Cedar seed is plentiful.
Cedar seed is light.
Other seed sources are plentiful.
Cedar restocks openings.
Cedars, other trees, and shrubs sprout in openings.
Fast growing shrubs & trees out-compete cedar in openings.
Matures to uneven-aged pure cedar stand.
Matures to mixed cedar stand.
Matures to deciduous hardwood islands within old cedar stand.

Figure 29. Effects of high winds in Atlantic white cedar wetlands.

acidity is reduced, and ammonia, phosphates, and chlorides increase via subsurface routes. The greatest overall impact is created by direct runoff.

Agriculture. The draining of swamp lands for row crop agriculture and damming to either flood cranberry bogs or fill reservoirs generally result in replacement by drier forest species (Little 1950; Laderman, unpubl.). Cultivation and draining level the hummock and hollow topography and may permanently and irreversibly destroy the soil microstructure (see Section 4.3).

Silviculture has exerted profound effects on forest composition, ranging from the complete local extirpation of Atlantic white cedar to the production of pure cedar stands. The results of clearcutting, selective harvest, post-harvest treatment, etc., are explored with "harvest" elsewhere in this chapter.

Non-point source load. Both agriculture and suburban development add significantly to the nutrient, heavy metal, total solids, and non-biodegradable content of the wetland water and soil into which they drain. Peat acts as a sink for DDT and for other similar non-biodegradable adsorbable molecules (Gorham 1987). Fertilizer, pesticide, herbicide, and animal and human wastes contribute to the non-point source load of ground and surface water.

Roadways. The long-term effects created by roadbeds are not fully comprehended. Extensive stands of cedar are flooded or drained by the creation of roads throughout the cedar's range. It is clear that they temporarily act exactly as any dam which floods adjacent areas and prevents the free flow of water and nutrients downstream. In addition, the effect on water quality of roadbase materials and runoff must be considered (Craul 1985 examines the impact of roadways on soils). Damage due to deer browse, winterkill, and windthrow are exacerbated at road edges (Little 1950; T. Dilatush, pers. comm.), where the growth of competing subcanopy vegetation is stimulated by the additional light and nutrient inflow.

On the other hand, increased light and heat favor the germination and rapid growth of cedar seedlings immediately adjacent to road cuts, and the local increase in moisture due to the channeling of water has a similar effect. Thriving, dense, even-aged, monotypic *Chamaecyparis* stands often line drainage ditches that accompany cedar forest roads.

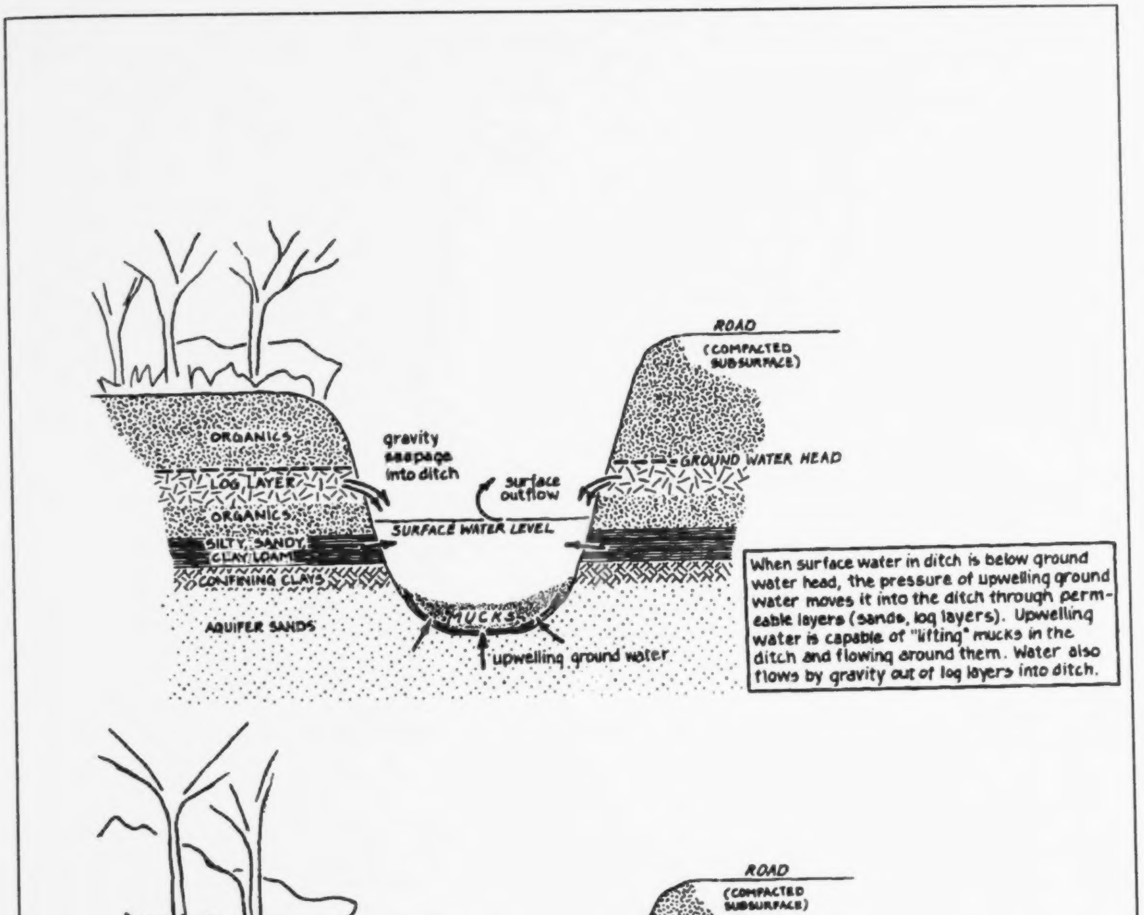
The complex hydrological effects of drainage ditches (illustrated diagrammatically in Figure 30) have a major overall impact on Atlantic white cedar forests. Normal water retention and slow subsurface sheetflow are replaced by rapid channelized surface flowthrough of water made virtually unobtainable to the wetlands. This problem is examined in the case study of Dare County, NC (Chapter 7).

6.2 MANAGEMENT

It would be expected that definitive guidelines for management of a tree that has been harvested since the first Europeans settled on the continent would have been developed long ago, yet this is not so. As with many other plentiful resources in the early days of development, the supply of cedar seemed endless. When all cedar that was easy to remove was gone, the operators moved on. If less desirable cedars remained, they were commonly taken for fence posts, shingles, or even firewood. Fast-growing hardwoods often replaced cedar, and the nature of the forest changed.

In this century, the U.S. Department of Agriculture kept records of the amount of wood being produced and wood available for harvest. As the units used were too large for all but the most extensive Atlantic white cedar stands, *Chamaecyparis thyoides* was lumped with red cedar (*Juniperus*) and northern white cedar (*Thuja*), in effect leaving no records for the species (Ward, unpubl.). Even these records were written in strictly merchandising terms: board feet and stumpage rather than numbers of trees or percent cover. Then came a time when Atlantic white cedar was less important; western red cedar, easier to lumber and in greater supply, largely supplanted its eastern swamp relative (Ward, unpubl.). Ironically, the advent of the conservationist ethic signaled senescence for protected cedar lands, while unprotected swamps were, with the toss of nature's dice, given some chance for renewal as cedar stands. Early in the 20th century, fire suppression became not only the forestry imperative, but a national ethic as well. As discussed earlier, fire or other catastrophe makes the regeneration of cedar stands possible. On managed lands, every effort was made to prevent and suppress wildfire.

Current real estate and silvical economic practices discourage the regeneration of lands now in cedar. Few lands commercially lumbered for Atlantic white cedar are owned by the harvester. Private landowners and the State and Federal governments lease out the lumber rights, generally on a 20-year basis, to timber companies. They rent the right to take out the timber for a set period; thereafter they have no interest in the land. At present, there are no regulations governing the condition in which the land is to remain. Commonly, the only leasing stipulations and restrictions refer to the condition of roads and ditches (P. Garrett, pers. comm.). The timing and manner of harvest, handling of slash,



When surface water in ditch is below ground water head, the pressure of upwelling ground water moves it into the ditch through permeable layers (sands, log layers). Upwelling water is capable of "lifting" mucks in the ditch and flowing around them. Water also flows by gravity out of log layers into ditch.

When surface water level is above ground water head, gravity pressure of elevated water pushes water through any sediment permeable enough to permit transmission.

Mucks don't generally reach the log layer elevation and water is free to move in and out.

Little water flows into sands because gravity pushes mucks tight against permeable areas of the ditch bottom, sealing them off.

Figure 30. The effect of ditches on swamp surface and ground water (from USFWS 1986b).

and condition of the soil surface after lumber removal are all options of the lumberman. There is no economic incentive for the lumberman or landowner to prepare a seedbed, maintain seed sources and seedling stock, or to promote wildlife habitat and ecosystem values.

Chamaecyparis thyoides reaches merchantable age in 50 to 70 years, but the timber-lease and marketing system prevents any feedback or potential reward to the lumber company for policies promoting regeneration of a tree that "pays off" after half a century. Today's lumber company, like its predecessors, moves on, this time to new leases. To profit from his land, the landowner chooses a forest or agricultural crop with shorter maturation time and an assured market.

In 1931 Korstian and Brush, whose work (together with that of Silas Little) remains a primary source for sound information on *Chamaecyparis thyoides*, wrote: "The objective of good forest management is to grow merchantable timber the fastest, most economical way." Their thoughts reflected the straightforward historical objectives for those studying the white cedar – objectives that were centered around commercial importance.

Today, the charge to managers of our protected wetlands includes matters as diverse as the prevention of habitat degradation; the promotion of wildlife values and esthetics; provision for public recreation and education; protection of water resources, including water recharge, discharge, and quality; the maintenance of gene pools and species diversity; and the preservation of rare and threatened species. These concerns coexist with the marketplace, both the market of cedar, and the market of land values.

With the change in objectives, it is therefore not surprising that we still find no simple, definitive guidelines for optimal management practices of cedar wetlands.

6.3 THE COMMERCIAL USE OF ATLANTIC WHITE CEDAR

Much of the following information on cedar harvest and merchandising was gathered by D. B. Ward (unpubl.), who treats the economic facets of cedar harvest in detail.

The most important contemporary commercial cutting of Atlantic white cedar is in North Carolina, with New Jersey and western panhandle Florida as secondary centers (Tables 10, 11). The wood is used where its properties of light weight, resistance to decay, and fragrance are of value, as siding and paneling for houses, planking for small to medium sized boats, fencing, decking, and shingles, with smaller quantities used for such specialties as lawn furniture and duck decoys. Ward (unpubl.) calculated that the 1986 wholesale value of the manufactured products was $10 million to $11.5 million annually, with a forest inventory of standing trees of between 170 and 180 million board feet. Annual production is estimated at 19 million board feet (U.S. Forest Service, pers. comm. to D.B. Ward). "Board foot" (bd. ft.) is defined as 1 ft by 1 ft by 1 inch, but the actual thickness is somewhat less.

Table 10. Production of Atlantic white cedar: 1899-1945. From data gathered by D.B. Ward (unpubl.).

Area	Year(s)	Production (million bd ft/yr)	Reference
ME-NY	1925-1929	0.65	Brush 1931
NJ	1899	>10	Steer 1948
	1912	1	
	1914	10	
	1931	0.02	
	ca 1940	1	
	1925-1929	1.87	Brush 1931
Great	1914-1917	>20	
Dismal	1921	0.046	
	ca 1940	5	
VA + NC	1920-1929	10.73	Brush 1931
NC	1899-1945	2-5	
	1914-1917	7	
	ca 1940	7	
FL	1907	8	Steer 1948
	1908-1945	±0.2	
AL	1910	13	
	1911-1945	0.3-5	
FL + AL	1925-1929	2.45	Brush 1931
Summary for NJ, VA, NC, FL, AL			
	1899-1908	13-20	Steer 1948
	1908-1916	20-32	
	1917-1945	6-14	
	1925-1929	15.7	Brush 1931

6.3.1 Large-scale Lumbering

Large-scale harvest, as practiced in North Carolina where the great majority of cedar is cut, is done with a gigantic amphibian feller-buncher (Figure 31), a machine specifically developed for harvesting wetland cedars. The machine's tractor-mounted articulated arms seize the erect tree, shear it at the base and place the cut trees in parallel rows. A man on foot then removes the tops and branches. A skidder seizes six to eight trees with its rear-mounted grapple and, using the cut tops and branches for traction, pulls the trunks to a roadway.

Table 11. Recent estimates of Atlantic white cedar timber volume.

	Standing timber ≥ 22 cm diameter		Timber removal		
Location	Year	million bd ft	Year	(bd ft/yr)	Source
ME - NY	1986	4	(combined with *Thuja*)		A
NJ	1971	54			NJ-F
	1986	32	1985	900,000 - 1 million	NJ-F
Delmarva	1986	3			A
Great Dismal	1986	40-50			A
East NC[a]	1985	60		17 million	A
NC	1984	203	1984	15,321,000	USFS
SC	1978	9			USFS
	1986	4-8			A
FL	1980	240	1980	740,000	USFS
FL + AL	1986	10-15	1985	400,000 - 600,000	A
TOTALS		452		>16 million	USFS
		170-180	1985	19 million ±500,000	A
Total annual value		$10 million - $11.5 million	A		

All data were collected by D.B. Ward (unpubl.) including that supplied by government sources as indicated. Considerable discrepancies exist between estimates of government, industry, and other sources.
A: Survey of industry and government (other than U.S. Forest Service [USFS]).
NJ-F: New Jersey Bureau of Forestry Management.
USFS: U.S. Forest Service unpublished data.
[a] Excluding Great Dismal Swamp; majority of trees are 70 years old.

In stands of normal density a single operator on a feller-buncher can cut and lay 400 to 500 trees per day, while in the most dense stands this may reach 800 stems per day. The usual rate of cutting is 0.4 ha per day per feller-buncher and support crew (G. Henderson, pers. comm.).

Most harvested trees are between 23 and 50 cm diameter; few exceed 60 cm dbh. The feller-buncher cannot handle trunks larger than 1 m in diameter. Such rare trees, missed in the harvests of the early 1900's, may be left standing. This process is most efficient in clear-cutting stands larger than four hectares, with densities of at least 5000 bd. ft., but preferably 10,000 bd. ft., per 0.4 ha (G. Henderson, pers. comm.).

6.3.2 Regeneration after Harvest

G. Henderson (pers. comm.) stated that the greatest natural reproduction is achieved in North Carolina when cutting is done on frozen earth in midwinter. The feller-buncher clearcut method can allow for healthy regeneration if slash is cleared sufficiently. In one North Carolina site, an abundant cover of fetterbush (*Lyonia lucida*) grew with the cedar initially, but cedars overtopped the shrubs by the fourth year. By the seventh year an almost solid healthy stand of cedar saplings covered the harvested area (A.D. Laderman and G. Henderson, unpubl. field notes). In other nearby sites where dense slash remained, cedar reproduction was almost nonexistent (J. Moore, J. Taylor, and A.D. Laderman, unpubl. field notes) (Figure 32). Selective cutting of cedar in a mixed stand discourages successful cedar reproduction (Little 1950).

6.3.3 Influence of Competing Vegetation and Slash

Slash left after lumbering severely reduces cedar seedling establishment (Akerman 1923; Korstian and Brush 1931; Little 1950). Cedar seedlings form dense stands in cleared areas between masses of slash. On logging rollways from which slash was removed, Korstian and Brush (1931) found 100,000 to 2 million seedlings per 0.4 ha three years after harvest, and more than 30,000 saplings per 0.4 ha five years later. Few seeds germinate, and fewer survive under the 0.6 to 1.2 m of dense slash often left after logging (Korstian and Brush 1931). Hardwood sprouts and shade-tolerant shrubs grow out over the slash and are rapidly covered with vines to form a virtually impenetrable mass.

6.3.4 Propagation

From seed. The USDA recommends pretreatment of cones for extraction of seed (Harris 1974) and placement of seeds in sealed containers if storage is necessary. Stratification (exposure of seeds to a moisture and temperature regimen) is believed to stimulate prompt seed germination, but optimal nursery practice has not yet been defined experimentally for the species (Harris 1974). Fall planting of seed is recommended in New Jersey (Little 1950).

From cuttings. A protocol for propagation by cuttings recommended by T. Dilatush (pers. comm.) follows:

Take cuttings in late autumn. Place in a half peat/half sand growing medium, 20 cm deep, over a relatively poor-percolation clay base, in board-sided beds. After 2 years, most seedlings are 30-45 cm. Cut from the bed in 20 cm soil squares. These transplant well into a rototilled sand/peat/clay "veneer" layer of improved soil over relatively impervious clay, with periodic sprinkling. Some clones have considerably more rootmass than others. In general, better rooted clones provide more height and girth in a shorter time.

Dilatush noted signs of winter stress on the faces of trees along road cuts through monotypic cedar stands following severe winters for many years after the original roadcut. Populations similarly exposed in the untouched forest, such as along the river edge face of a monotypic stand, do not appear

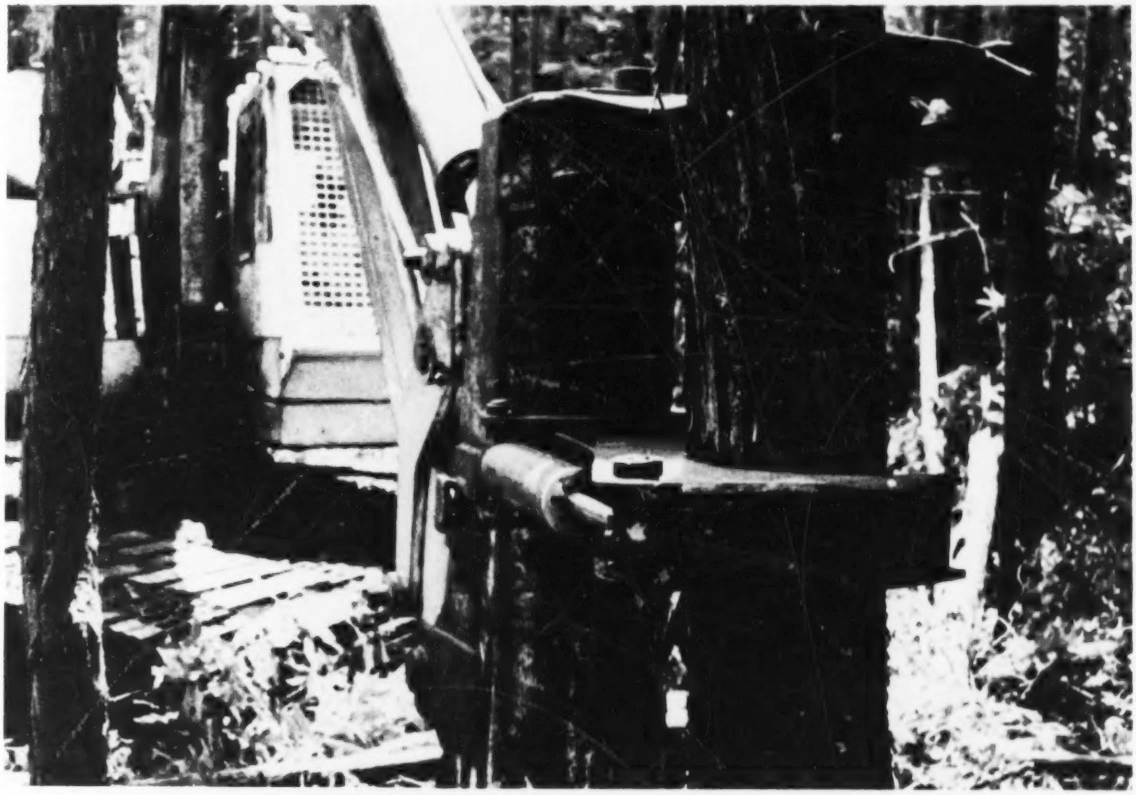


Figure 31. Amphibious feller-buncher harvesting Atlantic white cedar. Photograph courtesy Atlantic Forest Products, First Colony Farms, Edenton, NC.

stressed. Noting that such populations might be preadapted to exposure, Dilatush recommends selection of cuttings from them.

6.4 MANAGEMENT GUIDELINES

6.4.1 Introduction

Recommendations for harvest and management published prior to 1950 were reviewed by Little (1950). The approaches ranged from selective cuttings of the largest trees (Ashe 1894a), to shelterwood cutting (where a few seed trees remain) (Pinchot and Ashe 1897), and clearcutting of many dimensions and rotation lengths to produce an even-aged monoculture (e.g., Korstian and Brush 1931; Jemison 1945; Moore 1946).

On the basis of extensive field and laboratory observations, Little (1950) proposed an approach to cedar management that has remained the standard for the past three and a half decades. He made it clear that there were (as there still are) too many unknowns for any simple formula and that each procedure should be monitored and assessed for future guidance. Little's recommendations for harvest regimen, management of developing and mixed stands, and restoration follow.

6.4.2 Harvest Regimen

a. Manage cedar in even-aged tracts.

b. Harvest by clearcutting.

c. Remove or reduce slash.

d. Control competing hardwoods.

e. Control deer browse.

f. Cedars should be cut in strips; width of the strips should be determined by stand conditions and the distance of effective seeding (i.e., that which will result in the establishment of several thousand seedlings per hectare in a 5 - year period). Ideally, harvested strips should be no wider than 30-45 m. In mixed stands (25 - 50% cedar), maximum strip width should be 30-60-m. The densest pure cedar stands could be cut in 90 to 120 m strips.

g. Delay subsequent harvests in adjacent stands until a 30- to 90-cm well-stocked stand is established.

h. The maximum size of a single harvest should be 4 ha. This maximum applies to stands of at least 40 ha. The width of the cutting strips generally dictates the size of the harvested area.

i. Control developing hardwood understory.

j. Protect from wildfire - possibly by prescribed burning in areas surrounding selected stands.

6.4.3 Management of Developing Stands

Silas Little pioneered in his approach to cleaning and thinning. He recommended the assiduous repeated removals (cleanings) of competing hardwoods - by girdling or chemical treatment - until only pure cedar remained. He also generally opposed the intermediate harvest (thinning) of young cedar because this practice promoted both cedar windthrow and the development of competing underbrush and hardwoods.

6.4.4 Management of mixed stands

Recommendations for stands containing less than 50% cedar are more complex and problematical. In stands with 25% to 50% cedar, Little suggested:

a. Clearcut in narrow strips, less than 30-60 m; aim for a maximum number of cedar seed trees on the adjacent windward uncut edge.

b. After seedlings on the clearcut reach 0.3-1 m, clearcut another narrow strip.

In stands with less than 25% cedar:

a. Remove hardwoods and spindling cedars.

b. Leave at least 10-20 cedars with good-sized crowns per 0.4 ha.

In all cases, removal of slash and repeated cleanings of hardwood are required.

6.4.5 Restoration: Conversion of Hardwood Swamps

The establishment of cedar where none currently exists is costly and will be decidedly limited in application. In hardwood swamps, all trees must be felled, girdled, or poisoned; the slash burned; and hardwood sprouts cleaned repeatedly. Further treatment may be necessary to prepare a suitable seedbed. Burning or flooding may be useful.

Introduction of Atlantic white cedar may be accomplished by encouraging natural regeneration if seed sources are available, by seeding or planting seedlings. Seeding is preferable to planting of seedlings in most circumstances. The surface debris under a mature dense cedar stand is a good source of cedar seed. Surface debris may be collected and sown from November to May with fair results; 50% germination may be expected (Little 1950).

The role of white cedar in reforesting hardwood, non-cedar coniferous, shrub, and other types of wet sites is not yet well defined.

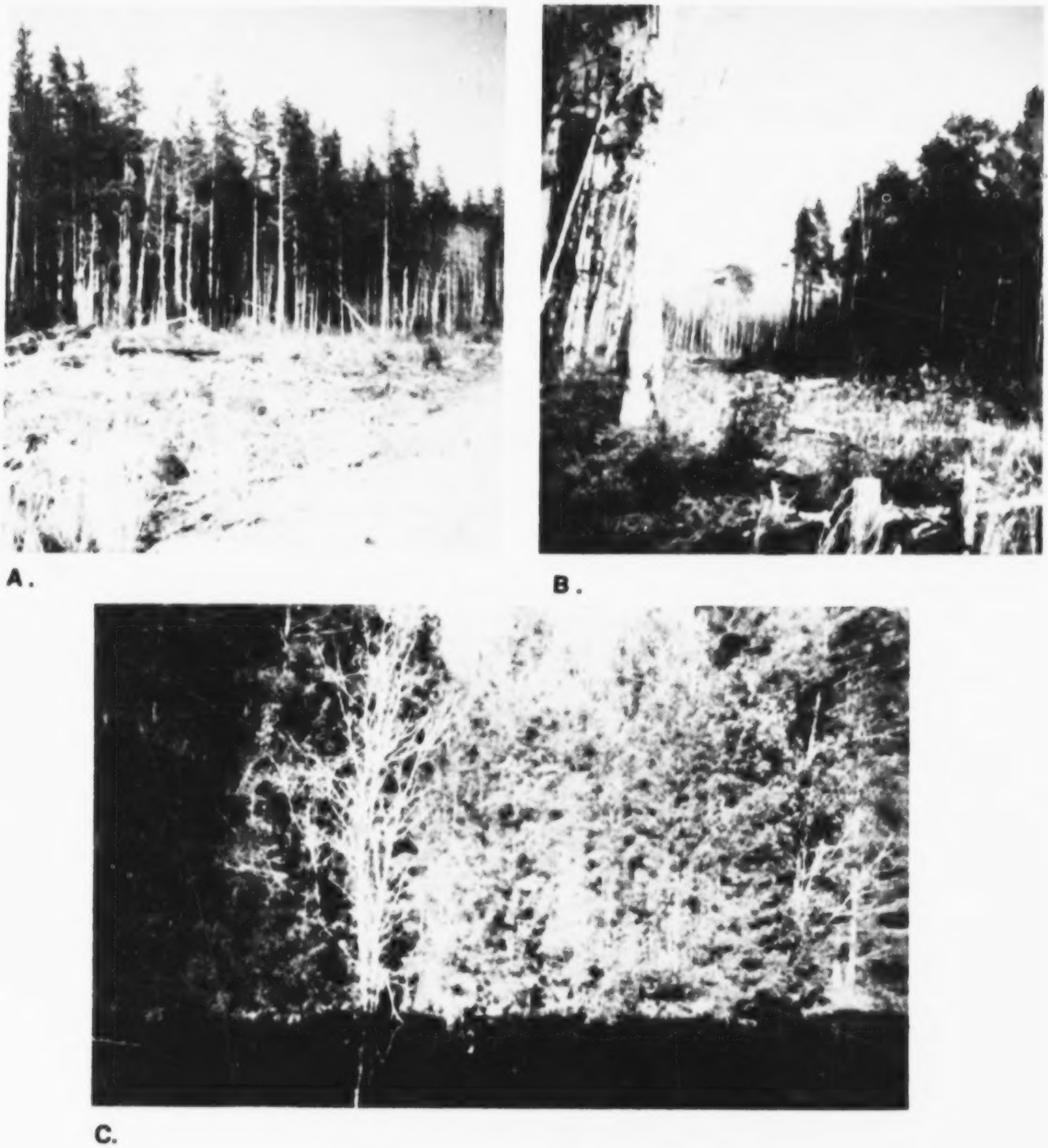


Figure 32. Atlantic white cedar regeneration after clearcut harvest of three different narrow cuts adjacent to mixed cedar forests, Dare County, North Carolina.

A. Site 1. One year after harvest. Heavy slash, some shrubs cover open area. Regeneration prospects: poor.

B. Site 2. Three to four years post-harvest. Heavy slash, shrubs, deciduous sprouts cover open area. Regeneration: poor to non-existent.

C. Site 3. Approximately eight years post-harvest. Slash and shrubs were removed soon after harvest. Regeneration: vigorous, of mixed composition similar to adjacent stands.

6.4.6 Fire as a Management Tool

United States government guidelines stress prevention and control of wildfire, but controlled burns are an accepted management tool for forest resources (e.g., see memos of U.S. Fish and Wildlife Service, Sept. 14, 1981, April 22, 1982, and April 11, 1983). S. Little, a pioneer in the use of fire as a silvicultural tool (Little et al. 1948a; Little et al. 1948b; Little 1953) recommended burning slash during high-water periods shortly after clearcut harvests to promote cedar regeneration. Complete burning is unnecessary: a fire that consumes only dead foliage and fine branches provides suitable conditions for cedar regeneration (Little and Somes 1961).

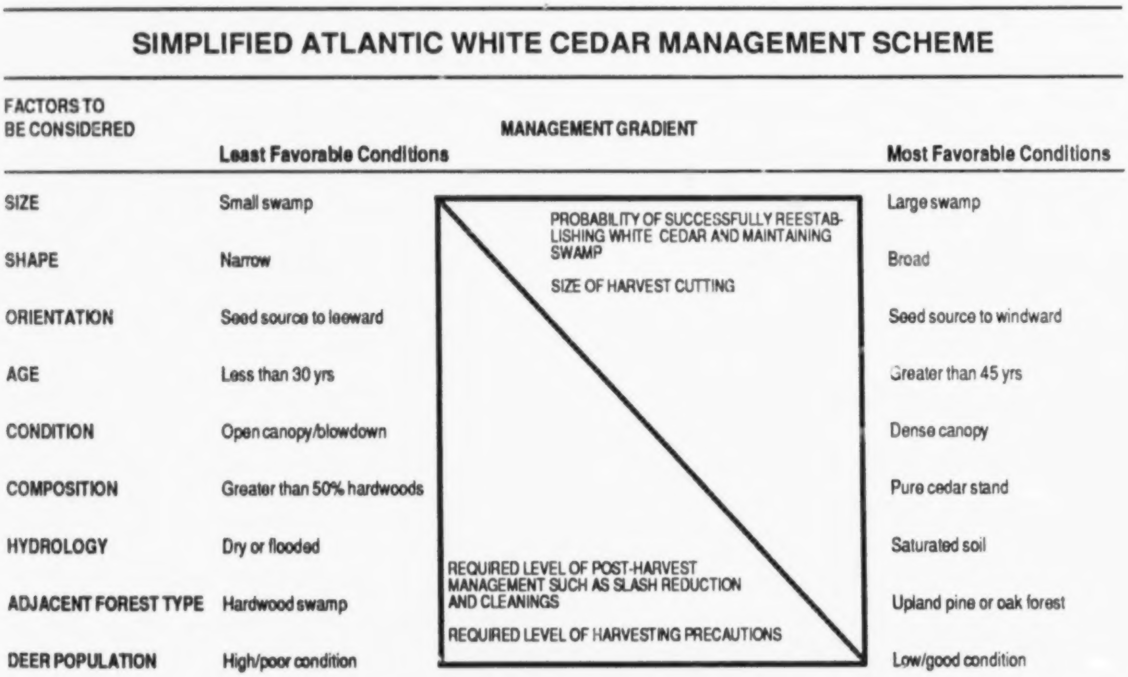
6.4.7 Cedar Wetlands as Firebreaks

The effect of a cedar swamp on a wildfire varies considerably, depending primarily on the depth of the water table, wind orientation in relation to the stand, wind velocity, and the width of the wetland. The majority of fires recorded in the New Jersey Pinelands have been able to breach cedar wetlands narrower than 300 m when impacted by head fires oriented perpendicularly to them. Broader swamps tend to act as firebreaks, especially when the water table is high (Little 1946, 1979; Windisch 1987).

6.4.8 Prediction of Success in Regeneration of a Cedar Stand

In a cedar stand completely cleared of higher plants by natural forces or clearcut harvest, the major factors to consider when predicting the potential success of cedar regeneration are the size, shape, orientation, age, condition, prior vegetational composition, and hydrology of the wetland, and the forest type and deer population of the surrounding area (Zampella 1987) (see Figure 33).

A large, broad swamp offers protection to the interior from all border influences, both natural (including deer browse) and human. An adjacent mature cedar stand provides a seed source most effectively when it is to the windward. A stand older than 30 years provides the maximum quantity of seed stored in the top peat layer. Dense canopy suppresses the growth of a heavy shrub layer which would in turn suppress and compete with cedar



SIMPLIFIED ATLANTIC WHITE CEDAR MANAGEMENT SCHEME

MANAGEMENT GRADIENT

FACTORS TO BE CONSIDERED	Least Favorable Conditions	Most Favorable Conditions
SIZE	Small swamp	Large swamp
SHAPE	Narrow	Broad
ORIENTATION	Seed source to leeward	Seed source to windward
AGE	Less than 30 yrs	Greater than 45 yrs
CONDITION	Open canopy/blowdown	Dense canopy
COMPOSITION	Greater than 50% hardwoods	Pure cedar stand
HYDROLOGY	Dry or flooded	Saturated soil
ADJACENT FOREST TYPE	Hardwood swamp	Upland pine or oak forest
DEER POPULATION	High/poor condition	Low/good condition

PROBABILITY OF SUCCESSFULLY REESTABLISHING WHITE CEDAR AND MAINTAINING SWAMP
SIZE OF HARVEST CUTTING
REQUIRED LEVEL OF POST-HARVEST MANAGEMENT SUCH AS SLASH REDUCTION AND CLEANINGS
REQUIRED LEVEL OF HARVESTING PRECAUTIONS

Figure 33. Factors that should be considered in planning a harvest are presented along a conceptual management gradient ranging from the least favorable to the most favorable conditions (adapted from Zampella 1987).

seedlings; conversely, canopy openings (existing prior to the clearcut) stimulate the growth of preexisting shrubs and hardwood saplings. A saturated, but not flooded, hummocky substrate promotes germination and vigorous growth of Atlantic white cedar. Adjacent hardwood stands supply competing sources of seed, which necessitates expensive, labor-intensive cleanings of hardwood saplings. Cedar swamp would be preferable to any other forest type adjacent to a stand to be cut, for it would serve as a potential cedar seed source and minimize the invasion of competing species.

6.4.9 Principles and Objectives

With the advice of Silas Little, Zampella (1987), Pinelands Commission scientist, outlined the optimal principles and objectives of cedar management as follows:

a. Public ownership and management is the most effective means of ensuring long-term maintenance.

b. Consider maintenance objectives before economic factors.

c. Manage for a diverse cedar inventory of all age classes.

d. Practice active management (see above) throughout the life cycle of a stand.

e. Each entire cedar stand should be considered as a unit for management.

f. Convert mixed stands or hardwood swamps to cedar.

g. Harvest only when it serves maintenance objectives.

h. Monitor to assess the effectiveness of methods used.

6.4.10 Implementation: New Jersey Pinelands; Great Dismal

The only areas for which cedar management guidelines are proposed or in place are in the State of New Jersey, primarily in the New Jersey Pinelands (described in Section 2.3.1); and the Great Dismal National Wildlife Refuge, Virginia and North Carolina (Section 2.4.1).

Pinelands. The New Jersey Pinelands Commission (NJPC) incorporates most of Little's (1950) recommendations in its management program (NJPC 1980; Zampella 1987; G. Pierson, pers. comm.), as discussed in Sections 6.4.2 through 6.4.9. The NJPC cooperates with, and is reviewed by, the New Jersey Bureau of Forest Management in supervising timber harvest. It must prepare detailed forestry management plans using management practices that protect site quality and natural resources, specifically considering stream crossings, bank protection, soil erosion, tree regeneration, and site treatment during and after harvest (NJPC 1980).

Great Dismal. In an effort to reverse the current trend in the Great Dismal Swamp, in which more mesic red maple and black gum are replacing the distinctive cypress and cedar stands (see Section 2.4.1), the USFWS (1986b) proposed an extensive management program. The most relevant portions of the plan are briefly outlined below.

a. Water Management: Implement full water conservation to alleviate surface-water loss and groundwater discharge. Hold water in ditches using both temporary and permanent structures.

b. Vegetation: Use rotational forest management to emphasize the enhancement of natural diversity and wildlife benefits. Manage Atlantic white cedar on a 100-year rotation (which does not allow for natural stand senescence). Aim to convert about an additional 1000 ha to cedar over 10 years. A sample of the implementation of the management scheme through the year 2020 is shown in Figure 34.

c. Ecological studies: Monitoring will be geared to understanding function and successional dynamics, with priorities as follows:

(1) develop a water budget model

(2) monitor ground water quality and flow

(3) survey understory vegetation to determine succession

(4) evaluate value to migratory songbirds

(5) monitor effects of resource management program on songbirds, wood ducks, black bear, deer, and endangered species.

The overall plan is to restore the original hydrology as far as possible and to slowly transform the present vegetation community (Figure 35) to one more closely resembling the original swamp. Figures 36 and 37 depict the community projected in 25 and 100 years if it remains unmanaged: in a century, cedar would virtually disappear, and cypress/gum would be drastically reduced. The entire program is flexible, and depends on continual monitoring and evaluation of the efficacy of the experimental management scheme. The complete plan, as well as alternative options and their implications, pertinent legislation, and a bibliography are contained in the Draft EIS of the Master Plan for the Refuge (USFWS 1986b) which is under review at the time of this writing.

6.5 THE FEDERAL ROLE

6.5.1 In National Forests

Four national forests contain *Chamaecyparis thyoides*: Croatan in North Carolina, Francis Marion in South Carolina, and Ocala and Apalachicola in Florida. Pursuant to the Forest and Rangeland Renewable Resources Planning Act (RPA) as amended by the National Forest Management Act (NFMA), the U.S. Forest Service prepared long-range land and resource management plans for the national forests.

Morman Branch Botanical Area (Ocala National Forest) and Mud Swamp/New River Wilderness (Apalachicola National Forest) contain about 95% of the Atlantic white cedar in the national forests in Florida. Management direction has not yet been developed for these areas, nor was direction given in the Final Land and Resource Management Plan.

6.5.2 In National Parks

The charge of the National Park Service, U.S. Department of Interior, is to preserve and protect their lands while permitting use that does not adversely affect the resource. At present, their policy is to use active management only to reverse the effects of human disturbance or to mitigate the impact of natural disasters.

The only National Park with Atlantic white cedar is the Cape Cod National Seashore, Orleans, Massachusetts. The swamp, co-dominated in part by red maple, contains cedar of varying ages and sizes with a substantial *Sphagnum* and herbaceous carpet. A boardwalk cuts through the cedar stand which is maintained for public education and passive recreation. The Service is currently conducting research to determine if the area should be actively managed.

6.5.3 In National Wildlife Refuges

The major National Wildlife Refuges (NWR) containing Atlantic white cedar are Great Dismal Swamp (GDSNWR) in eastern Virginia and North Carolina (described in Section 2.4.1), and Alligator River NWR in Dare County, North Carolina (to which all of Chapter 7 is devoted). The management plan for GDSNWR is outlined in Section 6.4.10; the current plan for Alligator River does not deal with cedar management (USFWS 1986c). A few small stands grow along streams and below dams in Sandhills NWR, South Carolina (J. Nelson, pers. comm.). Prime Hook Creek NWR, one of Delaware's important natural areas, also contains at least one small cedar stand (N. Dill, pers. comm.). There are no formal management programs for the minor cedar areas. The Refuge system is administered by the U.S. Fish and Wildlife Service.

6.5.4 On State and Private Lands

Federal support for private nonindustrial forestry is provided via grants to each state. Funds are available for nursery, wetlands, and forest management; the states are responsible for establishment of good management practice standards.

New Jersey is currently the only state that has an active management plan providing for regeneration of Atlantic white cedar (see Section 6.4 [esp. 6.4.10]). The program is in effect on State lands, and in the entire Pinelands National Preserve (G. Pierson, pers. comm.).

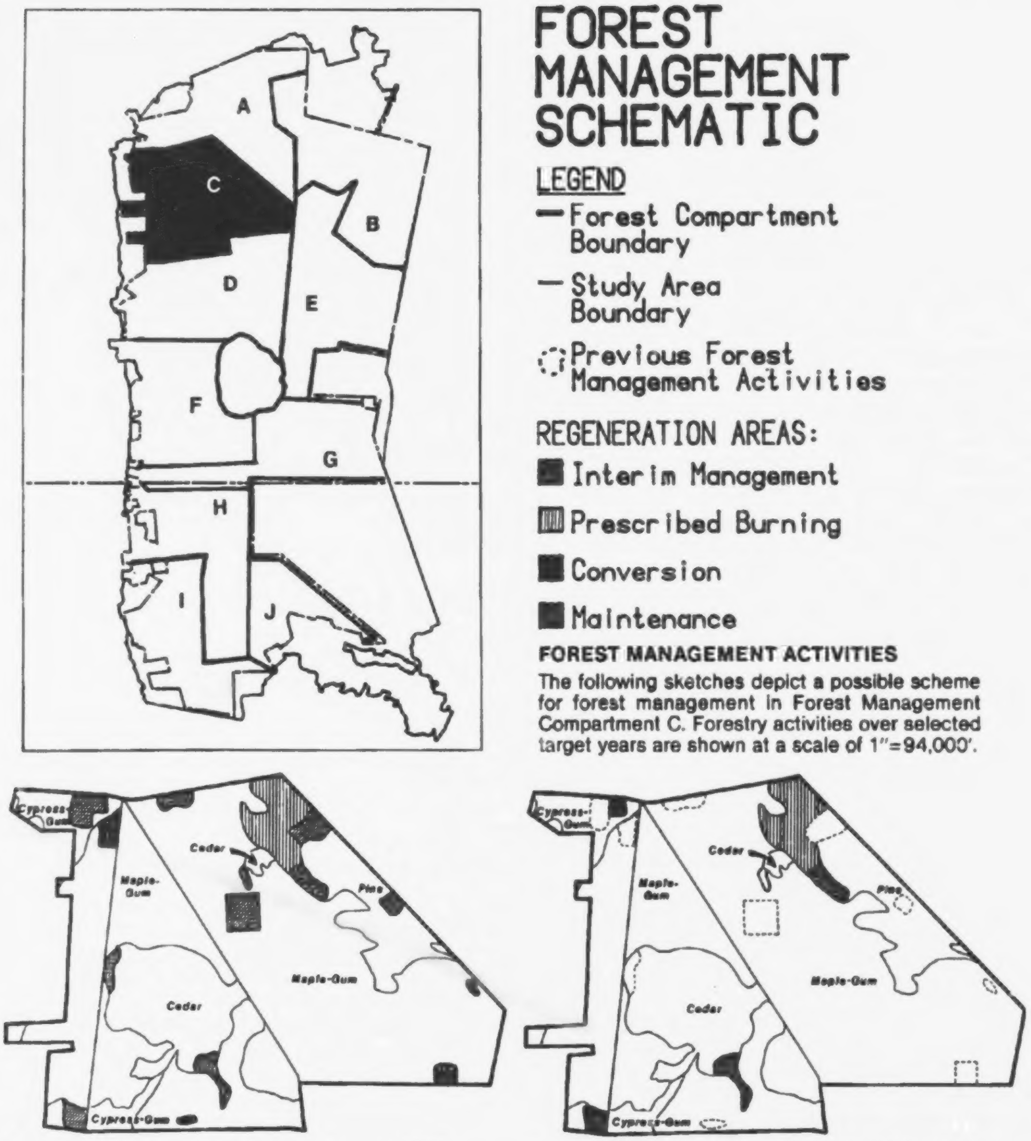
6.6 RESEARCH REQUIREMENTS

The overall objectives of research needed in the management of Atlantic white cedar wetlands are: 1) to define the biological, chemical, and physical spatial and temporal patterns required for cedar wetland maintenance, restoration, and creation; 2) to determine the most effective designs for restoration and creation of wetland functions; and 3) to develop methods to monitor and evaluate projects aimed at achieving these objectives.

Synthesis of existing information and the filling in of gaps in these data provide the framework for the first objective. The development of techniques to support the second and third aims is in its infancy and provides an opportunity for cedar wetland workers to make major contributions to the field of freshwater wetland creation and restoration.

Brief outlines of selected biological and physical research needs are at the end of Chapters 4 and 5; Chapter 7 ends with requirements pertinent to the Alligator River NWR, many of which are applicable to other sites.

The maintenance and revitalization of cedar wetlands are both the opportunity and the imperative for those entrusted with their management.



FOREST MANAGEMENT SCHEMATIC

LEGEND

— Forest Compartment Boundary

— Study Area Boundary

⬚ Previous Forest Management Activities

REGENERATION AREAS:

■ Interim Management

▥ Prescribed Burning

■ Conversion

■ Maintenance

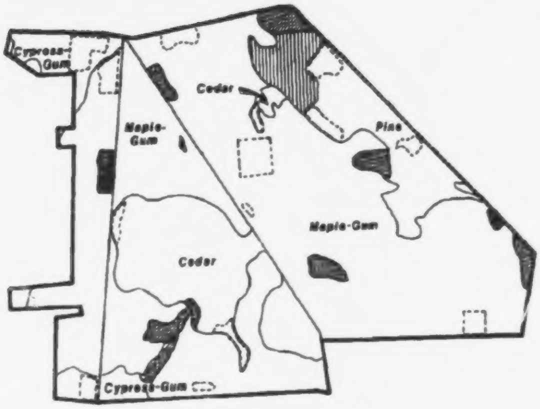
FOREST MANAGEMENT ACTIVITIES

The following sketches depict a possible scheme for forest management in Forest Management Compartment C. Forestry activities over selected target years are shown at a scale of 1"=94,000'.

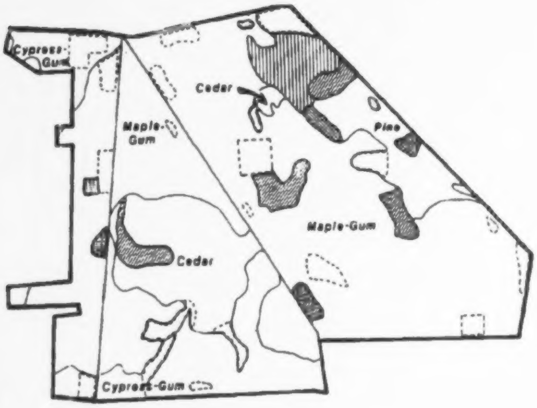
1. Forest regeneration activities in year 1990. Maintenance involves up to 475 acres, conversion involves up to 85 acres, and prescribed burning (limited to pine habitat) involves up to 2,000 acres. Regeneration activities occur at 10-year intervals.

2. Year 1995, illustrating activities which occur at less than 10-year intervals. Pine understory burning recurs every 5 years. Release of seedlings from competition takes place 3 to 5 years following regeneration, if needed.

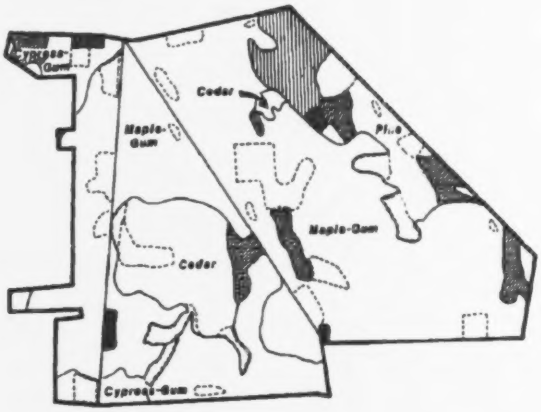
Figure 34. Detail of management plan for the Great Dismal Swamp National Wildlife Refuge aimed at promoting cedar regeneration. See location map, Figure 15 (from USFWS 1986b).



3. Year 2000. Additional cut and regeneration areas for forest maintenance and conversion are shown encompassing similar acreage as management in 1990.



4. Year 2010, showing additional cut and regeneration areas, with thinning now ocurring in some of the 20-year old pine stands.



5. Year 2020. Timber stand improvement occurs on an interim basis in some of the 30-year old stands.

Forest management activities would continue at 10-year intervals in Compartment C through the rotation cycle for all forest types at similar acreages.

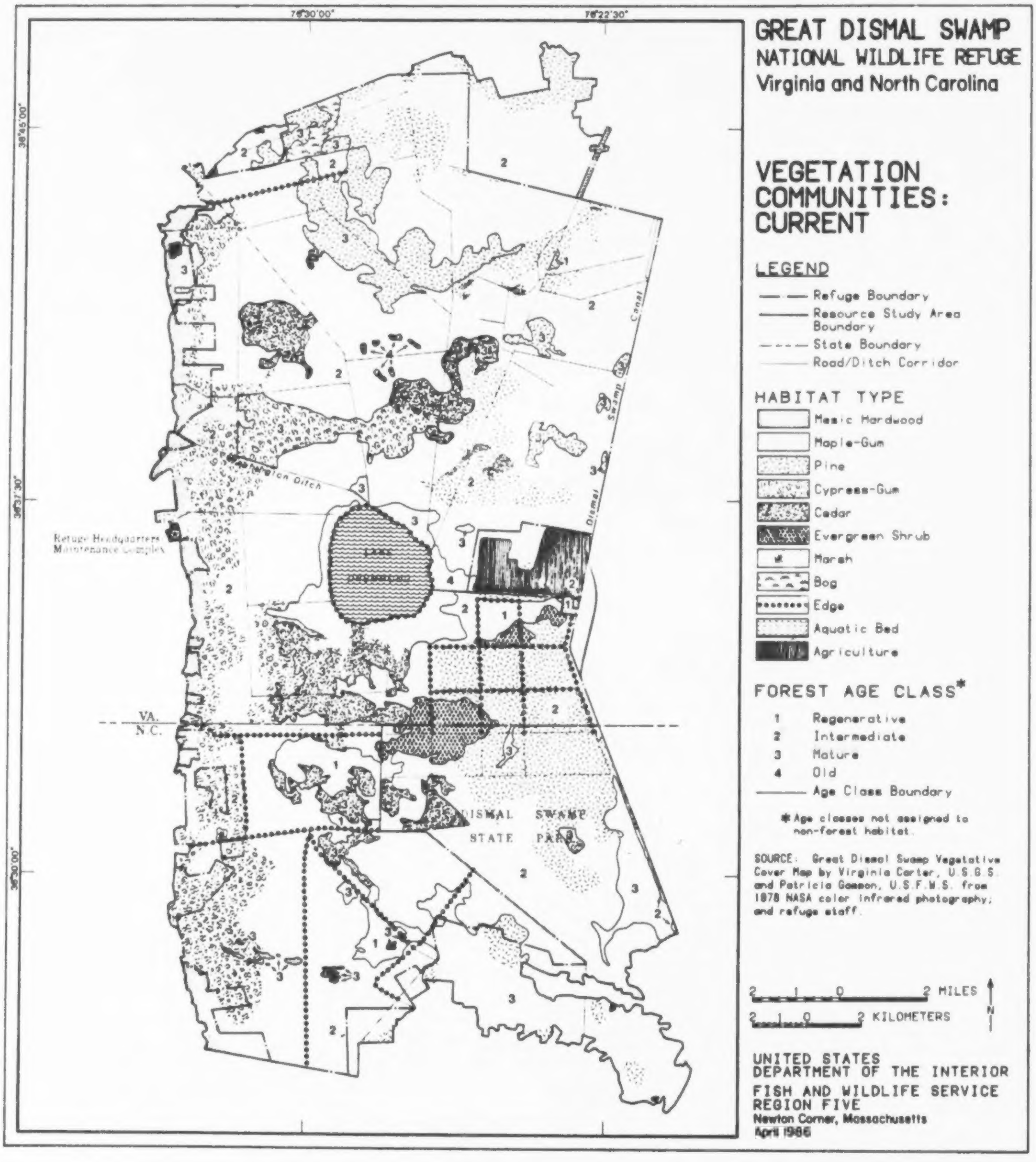


Figure 35. Major vegetation community types, Great Dismal Swamp NWR (from USFWS 1986b).

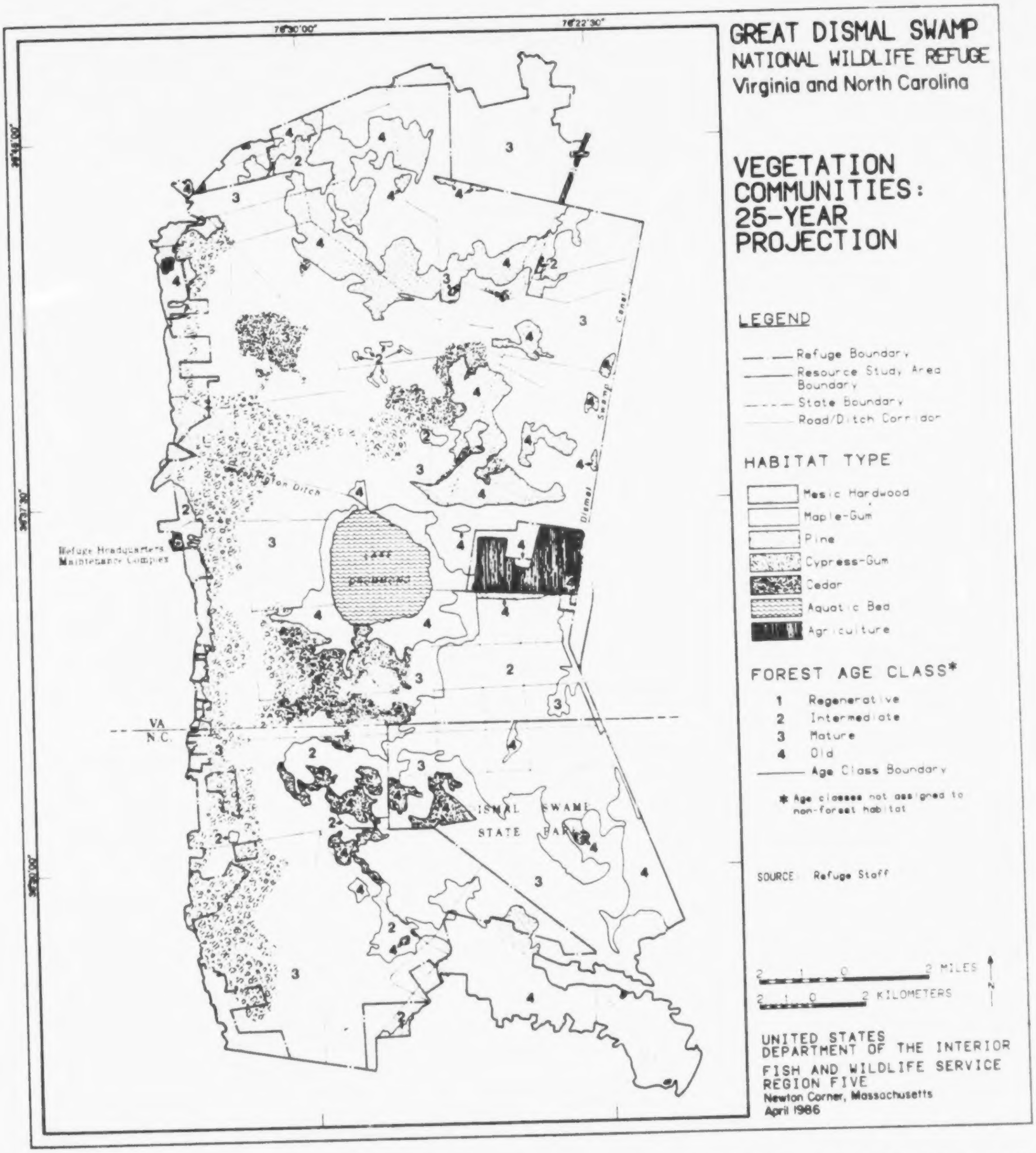


Figure 36. Vegetation community of the Great Dismal Swamp NWR in 25 years, as projected by planners if no management action is taken (from USFWS 1986b).

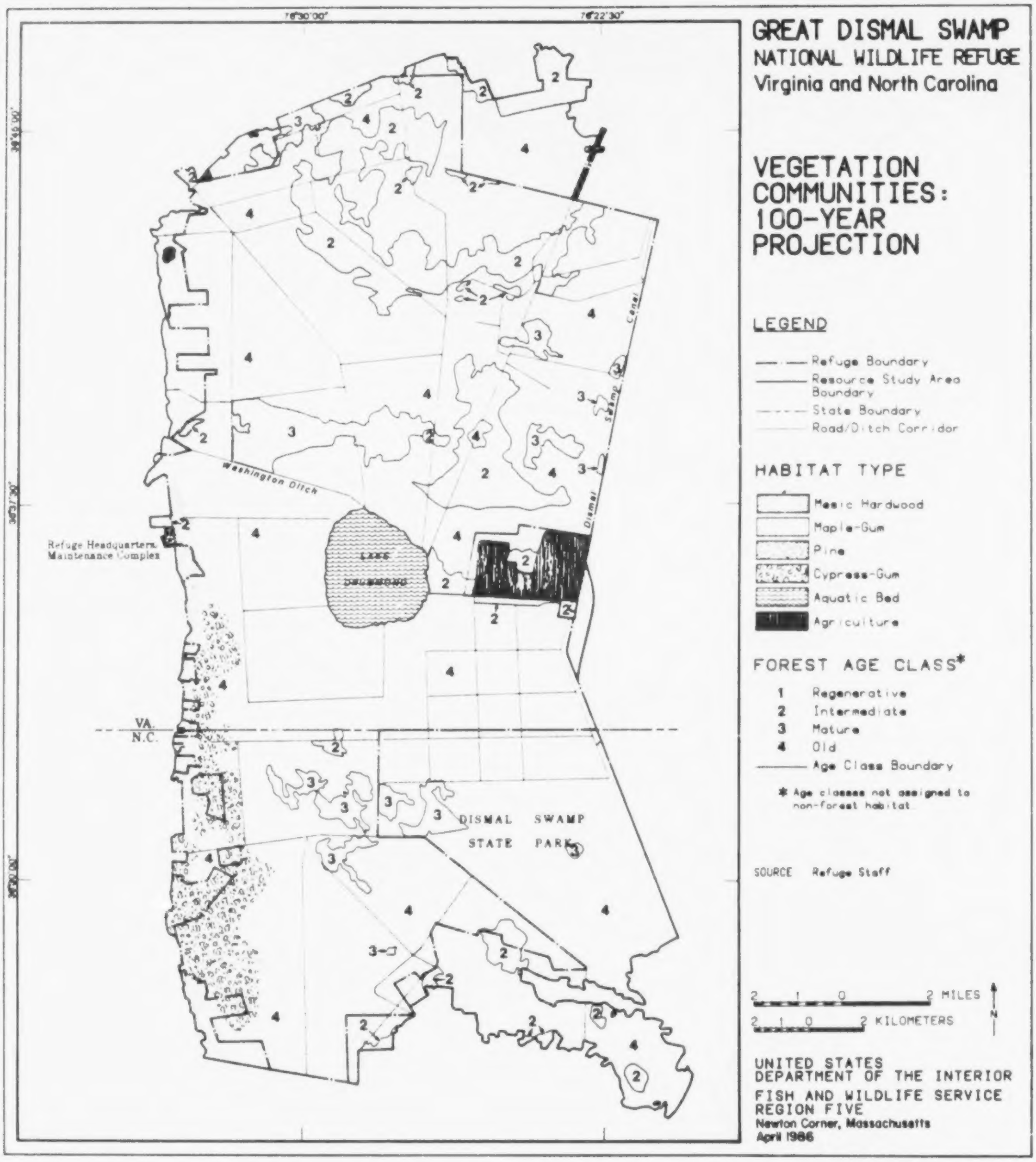


Figure 37. Vegetation community of the Great Dismal Swamp NWR in 100 years, as projected by planners if no management action is taken (from USFWS 1986b).

- CHAPTER 7 -

A CASE STUDY: ATLANTIC WHITE CEDAR WETLANDS IN DARE COUNTY, NORTH CAROLINA

by

Julie H. Moore and Aimlee D. Laderman

7.1 OVERVIEW

Mainland Dare County, in northeastern North Carolina, forms a northerly projection at the northeastern end of the low-lying Albemarle-Pamlico Peninsula (Figure 38). It is bounded on the north by Albemarle Sound, on the east by Croatan and Pamlico Sounds, and on the west by the Alligator River, which is used as a section of the Intracoastal Waterway. The peninsula is separated from the Atlantic Ocean by a string of narrow barrier islands.

Except as otherwise noted, data and analyses are previously unpublished field observations gathered by J.H. Moore while working on the USFWS wetlands mapping project and serving as supervisor of the Natural Heritage Program Inventory of Dare and Tyrrell Counties (Lynch and Peacock 1982; Peacock and Lynch 1982).

7.1.1 Historical Perspective

A century ago, Atlantic white cedar was a common tree of North Carolina's coastal wetlands extending inland to the Fall Line. W.W. Ashe (1894a), in an inventory of the State's forest resources, estimated that white cedar, one of the most valuable trees growing in the coastal plain, covered ca. 80,940 ha in North Carolina. By that time, the huge supplies of white cedar in the Dismal Swamp had been harvested; the most extensive white cedar forests (16,000 ha) were located in North Carolina's Dare, Tyrrell, and Hyde counties. Today, only fragments of the once expansive cedar forests of this area remain. The most extensive white cedar forests extant in North Carolina, and probably in the world, are located in the Dare County peatlands east of the Alligator River, in the Alligator River National Wildlife Refuge.

White cedar in this region grows in two types of associations: in distinctive, pure, seemingly even-aged dense stands, and in mixed forests with lowland conifers (cypress, pond and loblolly pine) and hardwoods (black gum [*Nyssa sylvatica* var. *biflora*], red maple, sweet bay). Black gum in this chapter refers only to the variety *biflora*, also known locally as swamp black gum. Few old-growth pure stands remain because these forests are the most profitable to harvest. The oldest and largest white cedars in the peatlands occur as scattered individuals about 27 m tall with 0.6 m dbh within the mixed swamp forest association. The habitats supporting these two cedar communities and the species associated with them are essentially the same. Fire and timbering histories appear to be the major factors in determining whether a dense, essentially pure white cedar stand develops or a mixed swamp with varying densities of cedar is established (Peacock and Lynch 1982).

7.1.2 Timbering History

The history of white cedar harvest in North Carolina is described in detail by Frost (1987 and unpubl.). McMullan (1982) provides a comprehensive account of harvest in the Alligator River Region. Major white cedar products in this region were shingles, buckets, cooperage materials, and telegraph and electric light poles (Ashe 1894a; Frost

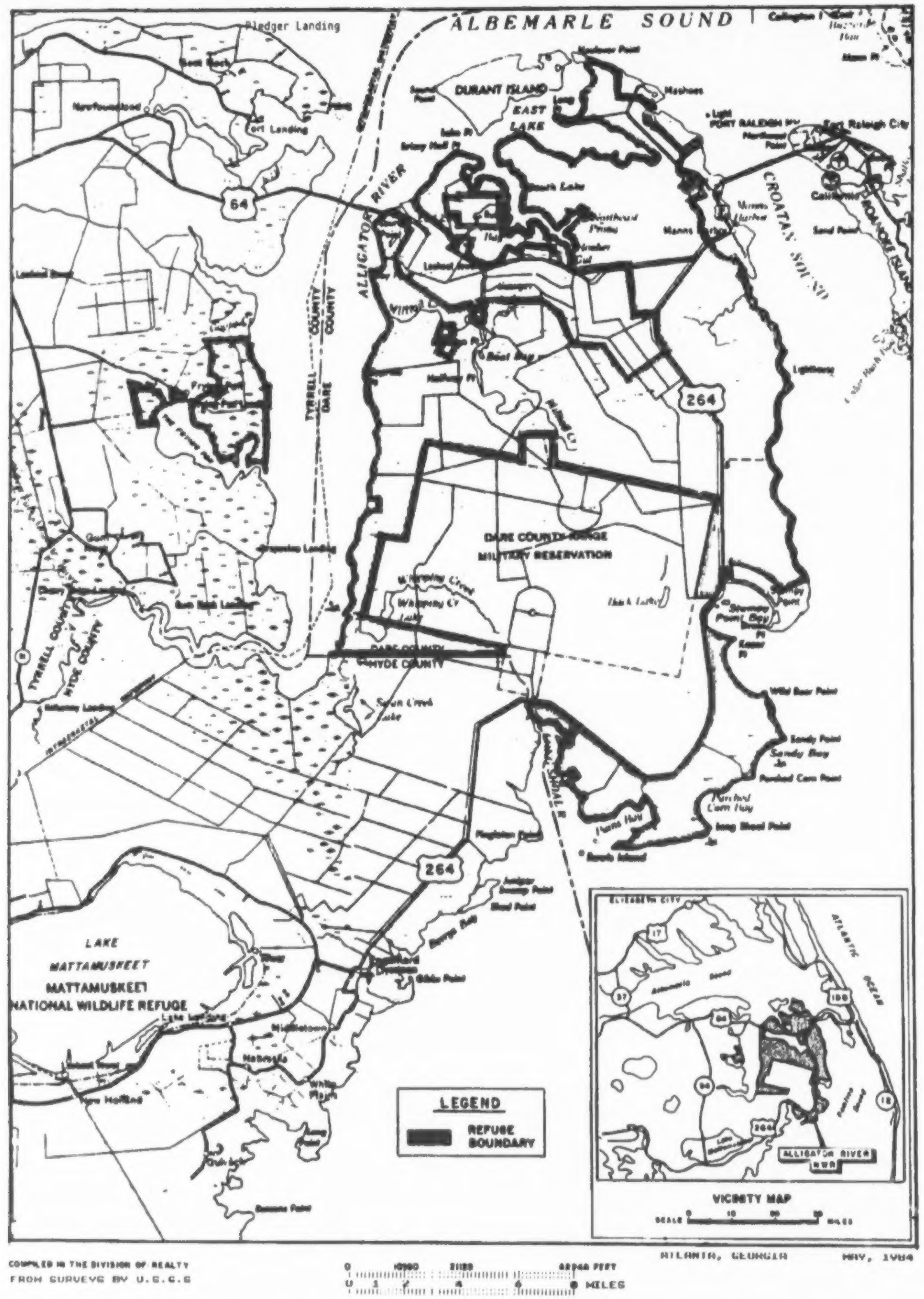


Figure 38. Alligator River (North Carolina) National Wildlife Refuge Including U.S. Air Force Dare County Bombing Range (from USFWS 1986c).

1987). Although cedar had been harvested since colonial days in the Alligator River region, it was not until the development of steam-powered logging in the mid-1800's that large-scale harvesting began. Roper Lumber Company, Richmond Cedar Works, Dare Lumber Company, and many smaller companies operated here between 1865 and 1953. Following the Civil War, an extensive system of narrow gauge logging railroads opened up previously inaccessible swamps to intensive harvest. Upon completing a harvest in one area, the rails were moved to another location. As is the practice today, the dense cedar stands were clearcut. Ashe (1894a) noted that due to access difficulty, white cedar down to the smallest diameter possible (20 cm dbh) was cut. Today, stands with an average diameter of 25 cm dbh are considered the minimum size-class profitable to harvest.

From timber cruise estimates, McMullan (1982) calculated that during World War I (1916-1919), all available cedar was cut by numerous operators on 64,750 ha. Only young hardwoods and some pine pulpwood remained. White cedar timber production was not important again until about 1980 (McMullan 1982).

Throughout the period of intensive cedar harvest no attempts were made to encourage natural regeneration, and harvest methods indicate little concern for future timber production. With the exception of a relatively small experiment from 1960 to 1970 by Westvaco lumbermen, no efforts were made to reestablish cedar forests following cutting (McMullan 1982).

The intensive harvest of white cedar and the associated swamp species prior to 1920 had a marked effect on the vegetation patterns that exist today. The timbering practices determined regeneration densities and species composition. However, the hydrology of the organic substrate was apparently not substantially altered, for the use of oxen and, later, narrow gauge rails to move timber did not necessitate elaborate permanent road construction and ditching.

Since the mid-1970's, Atlantic white cedar has been the species with greatest marketable value in the Alligator River region. An extensive system of roads, ditches, and canals was constructed to provide direct access to the pure, dense stands, particularly in Dare County. The effects of altered local hydrology on white cedar regeneration in Dare County have not yet been documented. It is known, however, that a shift towards drier soil conditions tends to prevent the self-maintenance and recovery of the original wetland vegetation types.

Today all accessible larger size- class stands in Dare County have been cut once again or are subject to harvest under commercial timber contracts. Pure stands that remain are generally composed of < 23 cm diameter trees that have been growing for up to 70 years. Scattered clumps and individuals of old growth trees still persist in the mixed-swamp forests.

7.1.3 Alligator River National Wildlife Refuge (ARNWR)

In the mid-1970's, the North Carolina Nature Conservancy initiated discussions about a donation of land (later known as Prulean Farms) on the Dare County mainland to conserve a portion of the region's unique peatlands that had been identified by the North Carolina Natural Heritage Program. Prudential Life Insurance Company purchased the property and, in March 1984, donated 47,755 ha in Dare and Tyrrell Counties to the U.S. Fish and Wildlife Service (see Figure 38). Most of the donated land is on the Dare County mainland, with approximately 2,430 ha in Tyrrell County west of the Alligator River. Timber rights to Atlantic white cedar stands on these lands are reserved until 1996 by Atlantic Forest Products, a subsidiary of the Canadian lumber firm, McMillan Bloedell, Inc. All timber rights have been subcontracted to the Alligator Timber Company. The area was designated as the Alligator River National Wildlife Refuge. In 1986, a draft 20-year master plan (USFWS 1986c) for the management of the Refuge was prepared, and is under review at the time of this writing. Within the boundaries of the Refuge is the 18,867 ha U.S. Air Force Dare County Military Reservation (Figure 38), which consists of a 2,470 ha bombing range surrounded by 16,390 ha of buffer lands. The Westvaco lumber company retained mineral rights, and Atlantic Forests Products retained rights (later subcontracted to Alligator Timber) to harvest tracts of white cedar until 1989 (USFWS 1985b).

The North Carolina Natural Heritage Program initiated discussions with the U.S. Air Force in 1983, recommending measures for the preservation of extensive natural areas.

In 1986 negotiations culminated with the registry by the North Carolina Department of Natural Resources and Community Development (NCDNRCD) of 7,690 ha as protected N.C. Natural Heritage Areas. Over 4,045 ha are high-quality cedar swamp forest contiguous with swamps of the Refuge, containing both pure and mixed white cedar associations. These Natural Areas will be managed by the U.S. Air Force for their natural values, with timber rights leased as noted above (USFWS 1985; Registry Agreement on file with NCDNRCD 1986).

7.2 PHYSICAL CHARACTERISTICS

7.2.1 Geology

Mainland Dare County is located on the Pamlico Terrace and bordered by water on three sides with a land connection to the south. The peninsula is based on recent Quarternary deposits consisting of surficial organic materials of varying thickness overlying undifferentiated and complexly interbedded layers of sand, silt, clay, and mollusk shells (Heath 1975).

The following discussion of recent geological processes follows Peacock and Lynch (1982). The Pamlico Terrace is the lowest and youngest of the several generalized surfaces of the Coastal Plain recognized as having been formed during periods of higher sea level. About 75,000 years B.P., the edge of the sea lay inland to a point now marked by the sandy ridge of the Suffolk Scarp (Daniel 1981) located 72 km to the west of the Dare mainland's current shoreline. At the peak of the Wisconsin glaciation, the sea was far below its modern level. As elsewhere in the cedar's range, the complex cycle of marine transgressions and regressions produced differing effects upon the topography of the alternately exposed and submerged surfaces. Rising seas slowed stream erosion by raising stream base levels, and planed off the previous surface features or obscured them with silts and muds. Falling sea level, in contrast, exposed areas of the continental shelf and rejuvenated streams, increasing downcutting and topographic relief.

7.2.2 Development of Peat Deposits

During the recent period of rising sea level, conditions favorable to peat formation have prevailed in Dare County and throughout the North Carolina Coastal Plain. During the past 10,000 years, peat has been forming under swamp forests, pocosins, and marshes, in blocked drainages, Carolina bays, and river floodplains (Otte 1981). Extensive sampling of peat depths, in conjunction with surveys of energy-grade peat deposits, indicate the presence of a subpeat system of southeast to northwest oriented stream channels (Ingram and Otte 1981, 1982) which have not yet been explored in detail.

7.2.3 Soils

Soils of mainland Dare County were mapped for the first time by Barnes (1981, and unpubl.; USACE 1982) (Figure 39). Organic soils predominate; the deepest histosols border the Alligator River and also occupy prepeat drainage channels in the interior of the county. Shallow histosols generally adjoin deeper peats in the soilscape; mineral series occur in areas which were interstream divides, slightly more elevated on the prepeat surface. Prepeat topography is now thoroughly obscured by organic deposits, as illustrated in Figure 22, where a cross section shows the relationships of peat depth, underlying mineral sediments, and soil series.

In Dare County, Atlantic white cedar associations are most frequently established on deep organic soils of the Dare and Pungo Series or on the shallower histosols of the Ponzer, Kilkenny, and Mattamuskeet series. Pure and mixed stands are occasionally associated with the Roper and Pettigrew series which are mineral soils with a histic epipedon (organic surface layer). In a few instances (e.g., west of the northern half of the bombing range), swamps including white cedar are found extending from organic soils onto poorly drained mineral soils which have a thick black or very dark gray highly organic loam surface (Hyde and Cape Fear soil series).

All of the soils of the region, classified as "hydric soils" by the Soils Conservation Service (USDA, SCS 1985a), are extremely wet year round, though water seldom pools on the surface. They are acidic (pH 3.0-4.0) (Barnes, unpubl.) and have large quantities of Atlantic white cedar and bald cypress roots, stumps, and logs throughout the profile. Surface and subsurface accumulations of charcoal indicate a history of severe fires in parts of the region (Otte 1981).

The transition zone between organic and mineral material averages less than 0.5 m, with little soil development in the underlying mineral layer (Dolman and Buol 1967). Daniels et al. (1984) believe that the lack of a distinct soil beneath the histosols indicates that the soils of the region have been continuously wet, with buildup of organic materials during wetter periods and loss during drier climatic times.

Soils suitable for white cedar establishment appear to be abundant in many areas of the Dare peninsula, principally concentrated in the western sector closest to the Alligator River.

7.2.4 Physiography and Hydrology

The Dare mainland lies within the Atlantic Coastal Plain Physiographic Province and is characterized by relatively flat terrain with elevations ranging from 3.7 to 0 m above mean sea level, declining gradually from west to east. As a consequence, the black-water stream systems that drain the peninsula are relatively short and slow-flowing.

The development of extensive Atlantic white cedar wetlands on the western sector of the Dare Peninsula, rather than to the east where pocosin vegetation dominates, appears to be related to the historic and contemporary flooding of the region rather than to depth of peat, soil series, or fire history, since the latter parameters are quite similar in both sections (Peacock and Lynch 1982). The complex interactions of organic soils, water flow, and development of the distinctive nonalluvial swamp forests of the peatlands, as condensed from Peacock and Lynch (1982), follow.

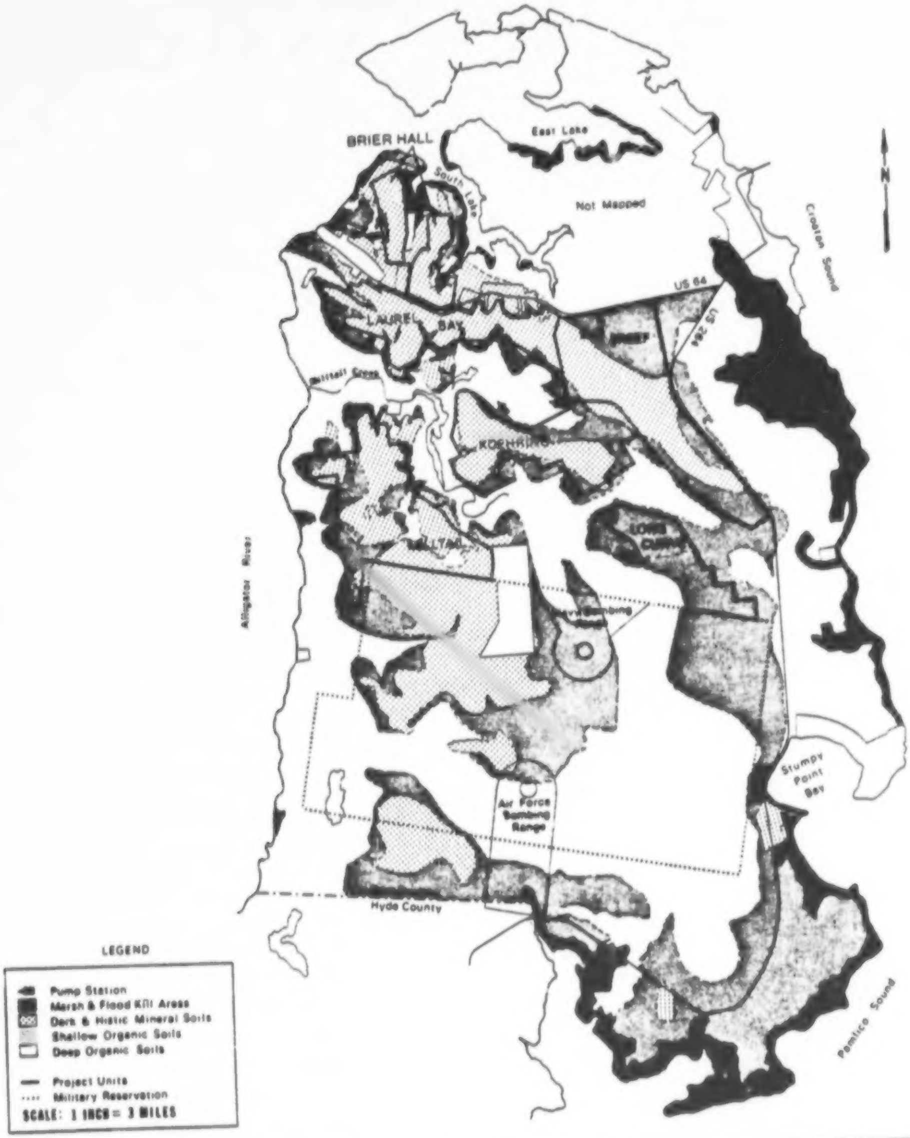


Figure 39. General soil types of mainland Dare County (from USACE 1982).

The cedar swamp forests along the Alligator River are nonalluvial in the sense that the Alligator is an estuary or embayed stream that neither transports a heavy sediment load nor has frequent high overbank flows. The mainland Dare swamp forests are physiognomically and hydrologically distinct from swamps of brown-water river flood plains; however, they appear to be more similar to those distant riverine swamps than to the nearby pocosins (see Section 7.3, esp. Section 7.3.4).

Pocosins and pure and mixed cedar forests are found on a similar range of peat depths. Charcoal layers sandwiched within forest peat profiles indicate that fire has occurred in such swamps without subsequent pocosin development (Otte 1981). Otte concludes that water-flow patterns are the major difference between cedar swamp forest and pocosin sites. In these swamp forests, the water flow is primarily into and through the systems; in nearby areas supporting pocosins, the major flow is out of the system. A large amount of Dare County cedar swamp water comes in from surrounding high ground or through flowing streams that carry clay and dissolved nutrients, whereas the major source of pocosin water is precipitation. Consequently, the peat that supports swamp forests has a higher average mineral content than does peat underlying pocosins (Otte 1981).

The flat terrain, combined with the high evapotranspiration rate of the dense vegetation and the low hydraulic conductivity of the organic soils of undisturbed cedar wetlands, causes water to move very slowly, predominantly overland, and through the root/litter mat (Skaggs et al. 1980; USFWS, unpubl. b). Historically, drainage patterns would have been overland to stream systems and thence into the nearest river or sound. However, the peninsula has been altered by highway and canal construction resulting in rapid drainage pathways generally less than 1.6 km long (USACE 1982). The pattern of hydrological change is very similar to that of the Great Dismal (see Section 2.4.1), but the alterations are not as drastic.

7.2.5 Climate

The Albemarle-Pamlico peninsula has a temperate climate with warm summers and mild winters. Winter temperatures seldom fall below -12 °C and summer temperatures often exceed 32 °C in July and August; humidity is usually high. The freeze-free season in mainland Dare County is 180 to 220 days long (USACE 1982). Precipitation averages from 114 to 137 cm per year, with peaks generally occurring July as a consequence of summer thunderstorm activity. Fall is usually the season of minimum rainfall. Annual amounts may be as low as 89 cm during dry years and as high as 203 during unusually wet years (USACE 1982). Because the Dare peninsula is surrounded by water, it is subjected to a strong coastal sea breeze regime. Prevailing winds are from the south-southwest, with average speeds of 14 to 17 km/hr (Copeland et al. 1983; USACE 1982).

7.2.6 Tidal Influence

The Dare peninsula is largely protected from the influence of lunar tides by the coastal barrier islands to the east, although dampened lunar tides of small magnitude do occur. Wind-generated tides are the principal source of water-level fluctuation within sounds, the Alligator River, and Milltail Creek. In the river and creek, rising tides usually result from west-northwest through east-southeast winds with falling tides usually resulting from southwest through west-southwest winds. Mainland Dare is subject to tidal inundation only under extreme conditions, and zones of flood-killed vegetation border the sounds where this has occurred (USACE 1982).

7.3 VEGETATION

7.3.1 Introduction

Atlantic white cedar associations, particularly the dense, monospecific stands, have interested North Carolina botanists and ecologists for some time (Ashe 1894a,b; Korstian 1924; Wells 1932; Buell and Cain 1943). However, it was not until the early 1980's, when attention was focused on pocosin and peatland losses, that any descriptive material or quantitative data on the vast coastal cedar peatlands was gathered. Natural area studies for mainland Dare, Hyde, and Tyrrell Counties (McDonald and Ash 1981; Peacock and Lynch 1982; and Lynch and Peacock 1982) are the principal published sources of information on white cedar associations of the peatland region. Unpublished substantiating data has been provided by intensive vegetation sampling by the USFWS Ecological Services Office. Wetland mapping for Dare County as a part of the National Wetlands Inventory project (USFWS, progress reports) has provided additional information.

Macrofossils in the peat profile indicate that white cedar has long been a component of the mixed swamp forests that dominate the western half of the Dare mainland (Otte 1981). The role that spontaneous fires, lightning, saltwater flooding, and hurricane windthrow played in originally opening habitat for white cedar colonization is completely obscured by the area's history of extensive timbering. The white cedar stands upstream from Milltail Lake, to the southeast of Sawyer Lake, and to the north and southeast of Whipping Creek Lake are the only ones on the Dare peninsula that are associated with streams or bodies of water.

The largest monospecific cedar stands of the region are relatively young. Generally they date from the period of intense timber harvest that ended before 1920; most of the stands that regenerated earlier than the 1920's have been harvested again or are under contract to be cut. The majority of the accessible pure stands are composed of trees 23 cm or less in diameter; stands with an average diameter of less than 25 cm are not economical to harvest today. If they are within 425 m of a road, pure stands as small as 4 ha are economical to harvest (G. Henderson, pers. comm.). Remnants of older age-class stands occasionally border clear-cuts. The largest and oldest white cedars in Dare County are found in mature non-alluvial swamp forests, where they codominate the canopy with the lowland conifers bald cypress, loblolly pine, and pond pine. Black gum is the most important hardwood species of this association in terms of frequency and percent cover. Individual cedars range from 46 to 69 cm in diameter and from 24 to 27 m in height. At many sites, majestic straight-trunked cedars tower above the surrounding mixed hardwood/conifer swamp forest.

Recent establishment of the dense cedar stands here, as in other parts of the species' range, has commonly followed removal of competing vegetation by clearcutting of similar stands or of mixed swamp forest. The type of hydric soil, whether a deep or shallow histosol or mineral soil, does not appear to be a major limiting factor to cedar establishment in western mainland Dare County. The hydrological patterns adjacent to the Alligator River seem to affect the development of swamp versus pocosin vegetation, rather than pure versus mixed cedar associations.

Though old growth canopy specimens predominate, subcanopy and juvenile cedar are also present in the mixed swamp forest (Peacock and Lynch 1982; USFWS 1982; S.W. Leonard and J. Moore, unpubl. field notes). Comparison of white cedar wetlands on the Dare mainland as mapped using 1976 aerial photography (USACE 1982) with those mapped in 1984 by the National Wetlands Inventory (USFWS, progress reports) reveal the extensive harvest that occurred during that period (Figure 40). Cedar continues to be cut under long-term timber contracts.

7.3.2 Wetlands Classification

Wetland mapping has been completed for mainland Dare County through a cooperative effort between the National Wetlands Inventory (USFWS) and the North Carolina Department of Natural Resources and Community Development.

All cedar associations in the Dare region are classified as palustrine wetlands with a saturated moisture regime (Cowardin et al. 1979; and see Section 1.2). Water is at or near the surface during most of the growing season, but since standing water is not necessarily present, the wetland character of the cedar forests is not always evident.

Although some cedar stands do not occur over deep organic soils, the National Wetlands Inventory maps use the descriptive symbol "g" (indicating an organic substrate) to separate cedar forests from other wetlands dominated by needle-leaved trees. On the wetlands map, pure and mixed cedar associations as well as the variable canopy composition of mixed associations are reflected in the symbols which indicate the estimated ratio of evergreen to deciduous needle-leaved trees (bald cypress), or to deciduous hardwoods and occasionally, evergreen broad-leaved trees (e.g., loblolly bay [*Gordonia lasianthus*] or sweet bay [*Magnolia virginiana*]).

7.3.3 Pure Stands

The dense, pure white cedar stands of all age classes are characterized by a distinctive ground-surface layer made up of a jumble of fresh and partly decomposed cedar trunks and intertwined greenbrier (*Smilax* spp.). Access into the stands is difficult; seemingly solid substrate may collapse under full body weight. Surface water is only occasionally evident, though the soil is almost constantly saturated. Where the density of trees is lower, the ground surface is less cluttered and more level, and shallow pools of water are present. A low diversity of associated species is characteristic. Few to no canopy or subcanopy trees interrupt the continuous dark-green cedar foliage. Black gum and, infrequently, red maple extend into the canopy but are more commonly a part of the subcanopy along with red bay, which varies greatly within and between stands both in height and density. Where the canopy is not completely closed, red bay may form a dense subcanopy above an evergreen shrub layer; occasionally it is within the shrub layer (Peacock and Lynch 1982). Generally the density of the shrub layer is determined by the maturity of the canopy, being most dense and impenetrable in the youngest stands. The shrub species present most consistently are fetterbush (*Lyonia lucida*), highbush blueberry

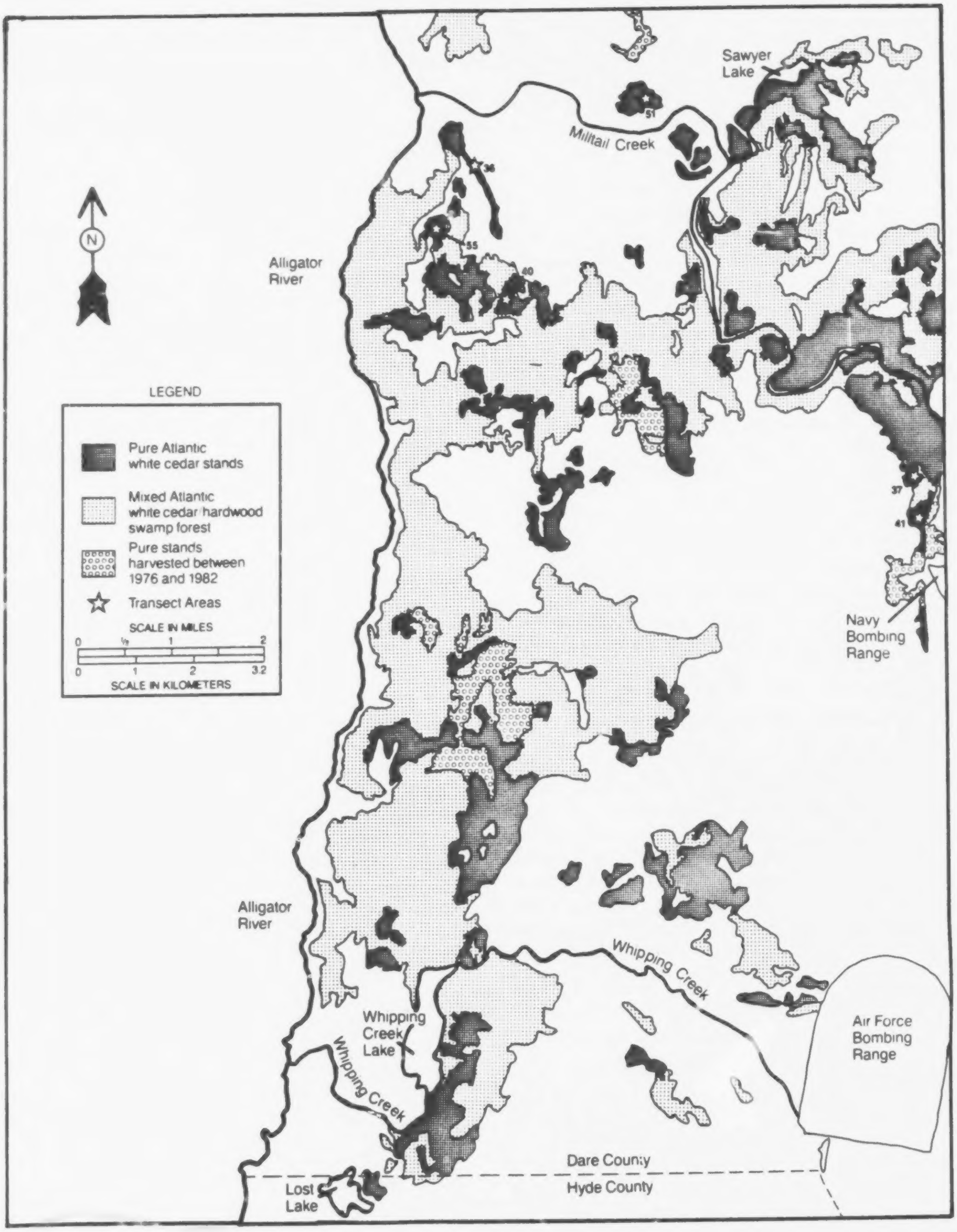


Figure 40. Atlantic white cedar wetlands of mainland Dare County, status in 1976 and in 1984, from aerial mapping (see text).

(*Vaccinium corymbosum*), and bitter gallberry (*Ilex glabra*). The herbaceous layer is consistently depauperate. *Sphagnum* spp. are found sporadically in patches where water stands on the surface. Mats of partridge berry (*Mitchella repens*) occasionally cover stumps and fallen logs.

Vegetation analysis. Sampling of six cedar stands by line intercept (Canfield 1941) and quarter point (Cottam and Curtis 1956) methods in 1982 by the USFWS (unpubl.) provides the only quantitative vegetation data available to date on Dare County white cedar (Table 12). Study sites are indicated on Figure 40. The average cedar dbh for six sites ranged from 13.7 to 32.5 cm. The largest diameter-class stand was harvested soon after sampling.

Canopy cover of white cedar ranged from 40% to 86%; cover contributed by additional species in the canopy and subcanopy ranged from 13% to 77%. Unpublished quarter point data delineating the character of each site is on file with the Office of Ecological Services, USFWS, Raleigh, NC.

In the largest size-class sampled (stand #041; dbh aver. 32.5 cm), white cedar contributed 81% of the cover. The four other species recorded in the canopy or subcanopy were black gum, red maple, pine, loblolly bay, and red bay. White cedar diameters ranged from 15 to 53 cm, the average being 32.5. The multiple subcanopy and shrub layers dominated by evergreen red bay and fetterbush under a tall canopy of white cedar was consistent with observations by Peacock and Lynch (1982) and by other wetland biologists mapping in stands of harvestable size.

7.3.4 Mixed forests

Pooled or shallow standing water is often present on the surface of mixed cedar stands. The proportion of white cedar in the mixed lowland conifer and hardwood swamps varies greatly. The harvest of certain species, particularly bald cypress and cedar, has determined in part what species are dominant today. The high proportion of lowland conifers and the abundance of evergreen shrubs make the physiognomy of these forests distinctly different from that of the forest dominated by black gum and/or cypress in flood plains of brown-water river systems. The principal canopy species occur here in proportions varying from site to site, with black gum the dominant hardwood present. Either white cedar or loblolly pine may be codominant. The amount of cover contributed by these species is more variable than that provided by black gum. White cedar is found throughout the mature swamp forest stands as majestic, straight-trunked, small crowned old-growth trees. Individual cedars range from 46 to over 61 cm dbh. Loblolly pine is more scattered, but often attains comparable diameters and usually exceeds cedar in height. Emerging from the canopy at many sites are scattered old-growth bald cypress left by loggers as cull trees. Bald cypress was probably a more significant component of the Alligator River swamps before selective timbering. Several other species reach the canopy, but are of far less importance than the principal species. Red maple is locally dominant where cypress, cedar, and black gum have been removed or thinned by logging. Pond pine and isolated large sweet bay are occasionally found in the canopy.

Table 12. Vegetation cover. Summary of line-intercept data from six Atlantic white cedar stands in Dare County, North Carolina showing the variations in cover ratios and sizes of cedar. From USFWS, unpublished HEP analysis data (1982).

Stand #	Ave-DBH white cedar (cm)	Total % cover white cedar	Total % cover other canopy-subcanopy species[a]	Total % cover shrub species[a]	Total % cover herb species[a]	Soil series
036	13.7	50	77	125	7	Pungo
051	15.7	76	13	160	106	Pungo & Belhaven
037	16.5	40	77	172	22	Pungo
055	20.6	51	55	179	0	Pettigrew
040	21.3	86	18	120	7	Belhaven & Pettigrew
041	32.5	81	36	166	71	Pungo

[a] Percent cover may exceed 100% due to the presence of overlapping vegetative strata.

Generally, the mixed swamp forest subcanopy is not well developed, consisting of smaller individuals of black gum and red maple with an occasional sweet bay. The shrub layer is rather open and generally consists of one or two species. A tall layer of red bay is frequently present, ranging from tall shrub to subcanopy height. The dominant low shrubs are usually sweet pepperbush and fetterbush, with scattered gallberry and highbush blueberry. Fetterbush is less dense in mixed swamps than in dense cedar stands. Ground cover is usually absent except for *Sphagnum* mats. The ground surface may be wet, with shallow standing water in scattered depressions. Cypress knees and many fallen logs add to the hummocky surface; however, the ground surface of mixed swamp forests is more open than that of pure cedar stands.

No quantitative data are available on mixed stands in which cedar is a codominant species. However, unpublished field notes of L. Peacock and M. Lynch (pers. comm.) describe several such sites. At a site near Milltail Creek Lake, white cedar and cypress form a closed canopy 21 to 27 m tall over a second canopy of black gum with some red maple and red bay about 12 m tall. Common shrubs recorded are sweet pepperbush, fetterbush, and bitter gallberry. Rotting stumps of cut cypress are common. Another mixed stand to the north, considered representative, contains white cedar 21 to 24 m tall with an average dbh range of 36 to 40 cm. The codominant hardwood component consists of black gum and red maple. Widely scattered hollow, old-growth cypress protrude from the cedar-hardwood canopy. Sweet bay, red bay, and red maple compose the subcanopy. Peacock and Lynch (1982) noted that sweet gallberry is more common at this site than elsewhere. Other shrubs they noted were fetterbush, maleberry (*Lyonia ligustrina*), bitter gallberry, and blueberry.

7.3.5 Unusual or Rare Plant Species

To date, no rare plant species have been found within the Atlantic white cedar associations of the Dare mainland. The highly acidic and continuously saturated character of the substrate, coupled with dense shade from the overstory and shrub layers, limits the potential for a diversity of all low-growing plants, as well as for unusual or rare ones. The few herbaceous species that have been found within Dare cedar forests are listed in Table 13.

7.4 FAUNA

The fauna of mainland Dare County palustrine wetlands has been investigated only in response to the major land alteration proposals of the past few years. Until recently, limited road access to the interior of the peninsula and inhospitable conditions have been major factors contributing to the basic lack of understanding of the dynamics of these unusual wetland habitats. A detailed summary of existing data on the fauna of the Dare mainland was prepared by the USFWS (Noffsinger et al. 1984) in a Fish and Wildlife Coordination Act report. The only additional source of information for the area is from Clark et al. (1985).

Table 13. Plant species characteristically associated with Atlantic white cedar wetlands in Dare County, North Carolina.

Canopy and subcanopy layer
- *Acer rubrum*
- *Gordonia lasianthus*
- *Magnolia virginiana*
- *Nyssa sylvatica* var. *biflora*
- *Persea borbonia*
- *Pinus serotina*
- *Pinus taeda*
- *Taxodium distichum*

Shrub layer
- *Amelanchier candensis*
- *Clethra alnifolia*
- *Cyrilla racemiflora*
- *Gaylussacia frondosa*
- *Ilex coriacea*
- *Ilex glabra*
- *Ilex opaca*
- *Leucothoe racemosa*
- *Lyonia ligustrina*
- *Lyonia lucida*
- *Myrica cerifera*
- *Myrica heterophylla*
- *Smilax laurifolia*
- *Smilax rotundifolia*
- *Smilax walteri*
- *Vaccinium fuscatum*
- *Viburum nudum*

Herbaceous layer
- *Mitchella repens*
- *Osmunda regalis*
- *Parthenocissus quinquefolia*
- *Peltandra virginica*
- *Rhus toxicodendron*
- *Sphagnum* sp.
- *Woodwardia areolata*
- *Woodwardia virginica*

The studies of Potter (1982a,b); Braswell and Wiley (1982); and Peacock and Lynch (1982), combining data on the fauna of both pure and mixed cedar forests in Dare County, catalogue 24 mammalian, 4 herptile, and 52 resident and breeding bird species (Appendix B and Table 14).

The southeastern five-lined skink, ground skink, and slimy salamander (Braswell and Wiley 1982), and carpenter frogs (Peacock and Lynch 1982) are the only herptiles thus far documented in various undisturbed cedar associations. Only six

Table 14. Summer birds of mainland Dare County North Carolina white cedar habitats. Data sources for habitat: L = Lynch (pers. comm.); PL = Peacock and Lynch (1982); P = Potter (1982a). Status codes: PR = Permanent resident; SR = Summer resident; PV = Permanent visitor (non-breeding); * = non-breeding in this habitat.

Species	Habitat Pure Cedar	 Mixed Cedar/Hardwood	Status
Green heron		PL	SR
Wood duck		PL,P	PR
Osprey		P	SR
Red-shouldered hawk		PL,P	PR
Bobwhite	P	PL,P	PR
Mourning dove		PL	PR
Yellow-billed cuckoo		PL,P	SR
Eastern screech-owl	L	PL	PR
Great horned owl		P	PR
Barred owl		PL,P	PR
Chimney swift		PL,P	SR*
Ruby-throated hummingbird	L	PL	SR
Belted kingfisher		PL	PV*
Red-bellied woodpecker		PL,P	PR
Downy woodpecker	L	PL,P	PR
Hairy woodpecker		PL,P	PR
Northern flicker		PL,P	PR
Pileated woodpecker	P	PL,P	PR
Eastern wood-pewee		P	SR
Acadian flycatcher		PL,P	SR
Great crested flycatcher	P	PL,P	SR
Eastern kingbird		PL	SR
Blue jay		PL	PR
American crow	L	PL	PR
Fish crow	L	L	PR
Carolina chickadee	P	PL,P	PR
Tufted titmouse		PL,P	PR
Brown-headed nuthatch		PL	PR
Carolina wren		PL,P	PR
Blue-gray gnatcatcher	L	PL	SR
Wood thrush		PL,P	SR
Gray catbird		PL,P	PR
White-eyed vireo		PL,P	SR
Red-eyed vireo		PL,P	SR
Northern parula	PL,P	PL,P	SR
Black-throated green warbler	PL,P	PL,P	SR
Yellow-throated warbler	L	PL	SR
Pine warbler	P	PL,P	PR
Prairie warbler	P	PL,P	SR
Black-and-white warbler		P	SR
Prothonotary warbler	P	PL,P	SR
Worm-eating warbler	PL	PL,P	SR
Swainson's warbler		PL,P	SR
Ovenbird		PL,P	SR
Common yellowthroat	P	PL,P	PR
Hooded warbler		PL,P	SR
Northern cardinal		PL,P	PR
Indigo bunting		P	SR
Rufous-sided towhee		PL,P	PR
Common grackle		PL	PR
Brown-headed cowbird	L	PL	PR
American goldfinch		PL	PR

species of mammals are recorded by Clark et al. (1985) for pure white cedar forests: Virginia opossum, gray squirrel, long-tailed weasel, white-tailed deer, black bear, and the Dismal Swamp short-tailed shrew, which was previously thought endemic to the Dismal Swamp. The other species listed (Appendix B) are found in mixed cedar swamps. Mainland Dare County is one of the few remaining coastal areas in the southeastern United States that currently harbors a substantial black bear population (Noffsinger et al. 1984).

Breeding bird diversity in Alligator River swamps is considered by Lynch and Peacock (1982) and Potter (1982a) to be exceptional both because of the diverse habitats present and the structural diversity of the mixed swamp forests in particular. The wood warblers are especially well represented, with 10 species breeding in the cedar forest communities. The black-throated green warbler, a very local breeder in the coastal plain of North Carolina, is abundant in mature pure and mixed Dare County cedar stands. Two other uncommon to rare nesting species in the coastal plain, Swainson's and worm-eating warblers, are also fairly common throughout the Alligator River cedar associations. Swainson's warbler prefers shrub thickets within mature mixed swamp forests stands having a closed canopy; it was not recorded in pure white cedar stands. Worm-eating warblers are less habitat specific, occurring in mature swamp growth, pure cedar stands and second-growth scrub (Peacock and Lynch 1982).

Breeding bird species diversity in this area exhibits an increase with increasing tree height, apparently as a consequence of the additional vegetational strata present (Noffsinger et al. 1984). Breeding species found in various cedar associations are listed in Table 14.

In winter the most abundant species observed by Potter (1982a) in pure cedar stands are pileated woodpecker, Carolina chickadee, and pine siskin. In mixed forests, robins are one of the most common winter residents feeding extensively on fruit of red bay, and when that preferred source is scarce, on greenbriar berries (Potter 1982a).

The rare Hessel's hairstreak butterfly (*Mitoura hesselli*), which is consistently found associated with white cedar throughout its range (see Section 5.3.3), has been collected as recently as 1980 at six white cedar dominated sites on the Dare County mainland (North Carolina Natural Heritage Program Data Base, unpubl.). Hessel's hairstreak is listed in North Carolina as a species of special concern.

7.5 MANAGEMENT PROBLEMS AND OPTIONS

The recent and ongoing white cedar harvest on the Dare County mainland resulted from contracts let before the establishment of the Alligator River Wildlife Refuge and registration of natural areas on the U.S. Air Force Dare Bombing Range. To assure that extensive cedar forests are once again a component of the wetland system, active management is necessary for both the vegetation and the supporting abiotic systems.

Baseline mapping covering the time and location of recent harvests and the size and density of timber removed, information essential for developing a management program, is available in the records of Atlantic Forest Products (G. Henderson, pers. comm.). Selective timber harvest of cedar for perpetuation of older stands is not a pressing need at this time and probably will not be for 50 to 75 years. As no documentation is yet available on the natural "break-up" or successional process in pure cedar stands in this region, monitoring the natural senescence of the few remaining older stands will be valuable. Extensive recently cut areas offer the opportunity for comparison studies of wildlife habitat and vegetation succession patterns under a variety of management regimes for slash, competing vegetation, and water.

Continuation of the U.S. Geological Survey hydrological monitoring program should help clarify the complex hydrodynamics of forested peatlands, while water levels essential for cedar growth are restored and regulated. Although many aspects and problems of the Alligator River NWR differ significantly from that of the Great Dismal NWR, the hydrological planning and experience in the Dismal (USFWS 1986b) may prove useful (see Section 2.4.1 and 6.4.10).

Fire is a major force in the development of vegetation types on the Dare mainland. Monitoring the long-term effects of wildfire and controlled burns (see Sections 6.1.1, 6.4.6, 6.4.7) will provide guidance for effective management.

The multiple uncertainties of management strategy for cedar wetlands, the lack of understanding of basic processes that govern them, and the patent paucity of hard data combine to forcefully document the urgent need for both basic and applied research on the ecosystem and its components. The Alligator River National Wildlife Refuge affords an excellent long-term observation and research site for these purposes.

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APPENDIX A. Flora Associated with *Chamaecyparis thyoides:* A Distribution Checklist

Compiled by Aimlee D. Laderman and Daniel B. Ward.

The following is a list of plants that have been observed growing in association with Atlantic white cedar in each state of its range. These records have been compiled from published studies of white cedar and its habitats, from herbarium records, and from recent communications by those currently engaged in field observation and research related to this species. A partial bibliography for the associated flora of each state appears in Laderman (1982).[1] The National List of Scientific Plant Names (NLSPN) (USDA, SCS 1982) has been used as the standard for botanical nomenclature wherever possible. Synonyms are included where different names have historically been used for the same plant. Common names follow Gray's Manual (Fernald 1950) and the National Wetlands Inventory Plant List (Reed 1986) with modifications reflecting regional usage. The first Checklist (Laderman and Ward 1987) was a product of the first Atlantic White Cedar Wetlands Symposium (Laderman 1987). The process of producing the list stimulated new botanical investigation in cedar wetlands and provided encouragement and a working body of information for studies in progress. Addenda and alterations to the first Checklist are the fruit of such interaction and the resulting additional data.

States are indicated by standard U.S. codes, listed North to South. MA-CC = Cape Cod; MA-W = Massachusetts west of Cape Cod. FL-E = peninsular East Florida; FL-W = "panhandle" West Florida.

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TREES

Scientific Name	Common Name	Distribution
Abies balsamea	Balsam-fir	ME NJ
Acer rubrum	Red Maple	ME NH MA-CC MA-W CT RI NY NJ MD DE VA NC FL MS
Acer rubrum v. *trilobum*	Red Maple	NY NJ SC
Asimina triloba	Pawpaw	VA
Betula alleghaniensis	Yellow Birch	NH MA-CC MA-W RI CT NJ
Betula lenta	Cherry Birch	ME RI
Betula papyrifera	White Birch	NH MA-W
Betula populifolia	Gray Birch	ME NH MA-CC MA-W RI CT NJ
Carpinus caroliniana	Blue Beech	MD VA NC FL
Chionanthus virginicus	White Fringetree	VA
Diospyros virginiana	Common Persimmon	DE

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[1] Appendix references are inserted in the main text reference list.

APPENDIX A. Flora: Trees

Scientific Name	Common Name	Distribution
Fagus grandifolia	Beech	DE MD NC
Fraxinus americana	White Ash	NH MD
Fraxinus caroliniana	Water Ash	VA NC FL-E
Fraxinus nigra	Black Ash	NH CT NJ
Fraxinus pennsylvanica	Green Ash	DE
Fraxinus profunda	Pumpkin Ash	FL-E
Fraxinus sp.	Ash	CT DE MD VA NC
Gordonia lasianthus	Loblolly Bay	NC SC FL-E
Ilex opaca	American Holly	MA-W NJ MD VA NC SC FL MS DE
Juniperus virginiana	Red Cedar	MD DE VA
Larix laricina	Larch	ME NH MA-W RI NJ NY
Liquidambar styraciflua	Sweet Gum	NJ MD VA NC FL MS
Liriodendron tulipifera	Tulip-tree	NJ DE VA NC SC FL-E FL-W MS
Magnolia grandiflora	Bull Bay	FL-E FL-W MS
Magnolia virginiana	Sweet Bay	NY NJ DE MD VA NC SC GA FL-E FL-W MS
Morus rubra	Red Mulberry	FL-E
Nyssa aquatica	Cotton Gum	VA
Nyssa sylvatica	Black Gum	ME NH MA-CC MA-W RI CT NY NJ DE MD VA NC SC FL
Nyssa sylvatica v. *biflora*	Black Gum	MD VA NC SC GA FL-E FL-W MS
Osmanthus americanus	Wild Olive	MS NC FL-E FL-W MS
Ostrya virginiana	American Hop Hornbeam	FL
Oxydendrum arboreum	Sourwood	VA NC
Persea borbonia	Red Bay	DE MD VA NC SC MS
Persea palustris	Swamp Bay	DE MD FL-E FL-W
Picea mariana	Black Spruce	ME NH MA-W RI CT NJ NY
Picea rubens	Red Spruce	ME NH NY
Pinus elliottii	Slash Pine	FL-E FL-W MS
Pinus palustris	Longleaf Pine	SC FL-W
Pinus rigida	Pitch Pine	ME NH MA-CC MA-W RI CT NJ MD
Pinus serotina	Pond Pine	DE MD VA NC SC
Pinus sp.	Pine	MD DE
Pinus strobus	White Pine	ME NH MA-CC MA-W RI CT NJ
Pinus taeda	Loblolly Pine	DE MD VA NC SC FL-E FL-W MS
Pinus virginiana	Jersey Pine	DE FL
Platanus occidentalis	Sycamore	VA
Populus balsamifera	Balsam Poplar	MA-CC MA-W
Populus heterophylla	Downy Poplar	NC
Populus sp.	Poplar	CT
Populus tremuloides	Quaking Aspen	ME NJ
Prunus serotina	Black Cherry	NJ DE MD VA
Quercus alba	White Oak	DE MD NC
Quercus bicolor	Swamp White Oak	MA-W
Quercus falcata	Southern Red Oak	NJ MD NC
Quercus laurifolia	Laurel Oak	VA NC FL-E FL-W
Quercus michauxii	Swamp Chestnut Oak	NC
Quercus nigra	Water Oak	VA NC FL MS
Quercus palustris	Pin Oak	DE
Quercus phellos	Willow Oak	NJ
Quercus prinus	Chestnut Oak	NJ MD
Quercus rubra	Red Oak	NY NJ MD
Quercus sp.	Oak	CT
Quercus velutina	Black Oak	NJ NC

APPENDIX A. Flora: Trees (Continued)

Scientific Name	Common Name	Distribution
Quercus virginiana	Live Oak	FL-E
Sabal palmetto	Cabbage Palm	FL-E MS
Salix babylonica	Weeping Willow	MA-CC
Salix floridana	Florida Willow	FL-E FL-W
Salix nigra	Black Willow	MD
Salix sp.	Willow	CT DE
Sassafras albidum	Sassafras	CT DE MD
Taxodium ascendens	Pond Cypress	FL-W
Taxodium distichum	Bald Cypress	MD VA NC SC FL AL MS
Thuja occidentalis	Arbor-vitae	ME NY
Tsuga canadensis	Hemlock	ME NH MA-W CT RI NJ NY
Ulmus americana	American Elm	NH MA-W RI
Ulmus americana v. *floridana*	Florida Elm	FL-E

Synonym	See: Accepted Name
Betula lutea	see: *Betula alleghaniensis*
Fraxinus pennsylvanica v. *lanceolata*	see: *Fraxinus pennsylvanica*
Fraxinus pennsylvanica v. *subintegerrima*	see: *Fraxinus pennsylvanica*
Persea borbonia v. *pubescens*	see: *Persea palustris*
Picea nigra	see: *Picea mariana*
Pinus australis	see: *Pinus palustris*
Populus tremula s. *tremuloides*	see: *Populus tremuloides*
Quercus falcata v. *pagodaefolia*	see: *Quercus falcata*
Quercus montana	see: *Quercus prinus*
Quercus virginiana v *maritima*	see: *Quercus virginiana*
Salix longipes	see: *Salix floridana*
Taxodium distichum v. *nutans*	see: *Taxodium ascendens*
Taxodium imbricarium	see: *Taxodium ascendens*
Ulmus floridana	see: *Ulmus americana* v. *floridana*

SHRUBS

Scientific Name	Common Name	Distribution
Agarista populifolia	Pipestem	FL-E
Albizia julibrissin	Silk-flower	NJ
Alnus maritima	Seaside Alder	MD DE
Alnus rugosa	Speckled Alder	MA-W CT NY NJ GA FL-E
Alnus serrulata	Tag Alder	NJ DE MD VA SC FL-E MS
Alnus sp.	Alder	ME NH
Amelanchier canadensis	Shadbush	MA-W NJ MD VA NC
Amelanchier obovalis	Shadbush	NJ
Amelanchier sp.	Shadbush	RI DE MD VA
Amelanchier X intermedia	Shadbush	NJ MD VA NC
Amphicarpaea bracteata	Hog Peanut	FL-E
Andromeda glaucophylla	Bog-rosemary	ME MA-W RI NJ-N
Apios americana	Groundnut	DE MD
Aralia spinosa	Hercules Club	DE MD VA
Arceuthobium pusillum	Mistletoe	RI NJ
Aronia arbutifolia	Red Chokecherry	MA-CC MA-W CT NY NJ MD DE VA NC SC GA FL-W

APPENDIX A. Flora: Shrubs (Continued)

Scientific Name	Common Name	Distribution
Aronia melanocarpa	Black Chokecherry	RI
Aronia prunifolia	Purple Chokecherry	ME MA-W RI NY DE MD
Ascyrum stans	St. Peterswort	MD
Baccharis glomeruliflora	Groundsel-tree	FL-E
Baccharis halimifolia	Groundsel-tree	NC DE
Berberis thunbergii	Japanese Barberry	MD
Berchemia scandens	Rattan-vine	FL-E
Bignonia capreolata	Cross-vine	VA NC SC
Bumelia aff. *lanuginosa*	Gum Bumelia	FL-E
Callicarpa americana	Beauty-berry	MD FL-E FL-W
Calycanthus floridus	Carolina Allspice	MS
Castanea pumila	Chinquapin	MS
Celtis occidentalis	Common Hackberry	VA
Cephalanthus occidentalis	Buttonbush	CT DE MD FL-E
Cercis canadensis	Eastern Redbud	SC
Chamaedaphne calyculata	Leatherleaf	ME NH MA-CC MA-W RI CT NJ
Clematis crispa	Leatherflower	FL-E
Clethra alnifolia	Sweet Pepperbush	NH MA RI CT NY NJ MD DE VA NC GA FL-W MS
Clethra alnifolia v. *tomentosa*	Sweet Pepperbush	SC
Cliftonia monophylla	Black Titi	FL-W MS
Cornus amomum	Red Willow	MD
Cornus amomum s. *obliqua*	Silky Dogwood	NH
Cornus florida	Flowering Dogwood	CT DE VA GA
Cornus foemina	Stiff Cornel	FL-E FL-W
Cornus sp.	Dogwood	CT DE
Cyrilla racemiflora	Titi	NC SC GA FL-W AL MS
Decumaria barbara	Climbing Hydrangea	VA NC FL-E
Empetrum nigrum	Black Crowberry	ME
Epigaea repens	Trailing Arbutus	NH DE
Euonymus americanus	Strawberry-bush	DE MD FL-E FL-W
Fothergilla gardenii	Witch Alder	SC GA
Gaultheria hispidula	Creeping Snowberry	ME NH MA-CC MA-W RI CT NJ
Gaultheria procumbens	Wintergreen	NH MA-W CT NJ DE MD VA NC
Gaylussacia baccata	Black Huckleberry	ME MA-CC MA-W RI NJ
Gaylussacia dumosa	Dwarf Huckleberry	ME MA-CC MA-W RI NJ SC
Gaylussacia frondosa	Dangleberry	MA-CC MA-W RI NY NJ MD NC SC
Gaylussacia mosieri	Huckleberry	SC FL-W
Gaylussacia sp.	Huckleberry	DE
Gelsemium rankinii	Yellow Jessamine	FL-W
Gelsemium sempervirens	Yellow Jessamine	VA NC FL-E
Hamamelis virginiana	Witch Hazel	MA-CC MA-W CT NY MS
Hypericum brachyphyllum	St. John's-wort	FL-W
Hypericum densiflorum	St. John's-wort	NJ MD
Hypericum fasciculatum	St. John's-wort	FL-W
Ilex cassine	Yaupon Holly	FL-E
Ilex coriacea	Large Gallberry	VA NC SC GA FL-E FL-W MS
Ilex decidua	Possum-haw Holly	VA NC
Ilex glabra	Gallberry	MA-CC MA-W NY NJ MD DE VA NC SC FL-W MS
Ilex laevigata	Smooth Winterberry	ME NH MA-CC MA-W RI NY NJ DE MD SC
Ilex montana	Mountain Winterberry	NJ
Ilex myrtifolia	Myrtle-leaved Holly	FL-E FL-W

APPENDIX A. Flora: Shrubs (Continued)

Scientific Name	Common Name	Distribution
Ilex verticillata	Black Alder	ME MA-CC MA-W RI CT NY NJ DE MD VA
Ilex vomitoria	Cassine	FL-E FL-W MS
Illicium parviflorum	Star Anise	FL-E
Itea virginica	Tassel-white	NJ MD DE VA NC SC FL-E FL-W MS
Kalmia angustifolia	Lambkill	ME NH MA-CC MA-W RI CT NJ DE VA NC SC
Kalmia cuneata	White Wicky	NC SC
Kalmia latifolia	Mountain Laurel	MA-W RI CT NY NJ DE MD VA FL-W MS
Kalmia polifolia	Pale Laurel	ME MA-W RI NJ
Ledum groenlandicum	Labrador Tea	ME
Leiophyllum buxifolium	Sand Myrtle	NJ SC
Leucothoe axillaris	Downy Leucothoe	VA NC FL-E FL-W
Leucothoe racemosa	Fetterbush	MA-CC MA-W RI CT NY NJ MD DE VA NC SC FL-E AL
Ligustrum sinense	Chinese Privet	VA NC
Lindera benzoin	Spicebush	MA-CC MA-W CT NY NJ MD VA FL-E
Lonicera japonica	Japanese Honeysuckle	NJ DE MD VA NC
Lonicera sempervirens	Coral Honeysuckle	VA NC FL-E
Lyonia fruticosa	Staggerbush	FL-W
Lyonia ligustrina	Maleberry	ME NH MA-CC MA-W RI CT NJ DE MD VA NC
Lyonia lucida	Fetterbush	VA NC SC GA FL-E FL-W MS
Lyonia mariana	Staggerbush	NJ SC
Matelea gonocarpa	Smooth Spiny-pod	FL-E
Mikania cordifolia	Climbing Hempweed	FL-E
Mikania scandens	Hempweed	NJ DE MD
Myrica asplenifolia	Sweet-fern	ME CT
Myrica cerifera	Wax Myrtle	MD NC FL-E FL-W MS
Myrica gale	Sweet Gale	ME MA-CC MA-W RI
Myrica heterophylla	Wax Myrtle	NC SC FL-W
Myrica inodora	Bayberry	FL-W
Nemopanthus mucronatus	Mountain-holly	ME NH MA-CC MA-W RI CT NY NJ
Myrica pensylvanica	Bayberry	MA-CC CT NJ DE MD VA
Nemopanthus mucronatus	Mountain-holly	ME NH MA-CC MA-W RI CT NY NJ
Parthenocissus quinquefolia	Virgina Creeper	MA-CC MA-W NY NJ DE MD VA NC FL-E
Phoradendron flavescens	American Mistletoe	MD VA NC SC
Pieris phyllyreifolia	Climbing Fetterbush	FL-E FL-W
Pinckneya pubens	Fever-tree	FL-W
Quercus ilicifolia	Bear Scrub Oak	ME NJ
Rhamnus frangula	Alder Buckthorn	MA-W
Rhapidophyllum hystrix	Needle Palm	FL-E
Rhododendron canadense	Rhodora	ME MA-CC RI
Rhododendron chapmanii	Chapman Rhododendron	FL-W
Rhododendron maximum	Great Laurel	MA-CC RI CT NJ
Rhododendron periclymenoides	Pinxter Flower	CT NY VA NC
Rhododendron serrulatum	Rhododendron	FL-E FL-W MS
Rhododendron sp.	Rhododendron	MA-W DE MD VA
Rhododendron viscosum	Swamp-honeysuckle	MA-CC MA-W RI CT NY NJ MD VA NC SC
Rhus copallina	Winged Sumac	DE VA NC
Rhus glabra	Smooth Sumac	CT
Rosa palustris	Swamp Rose	MA-W CT MD DE NC VA
Rosa sp.	Rose	MA NJ
Rubus argutus	Blackberry	VA NC FL-E
Rubus cuneifolius	Sand Blackberry	VA NC

APPENDIX A. Flora: Shrubs (Continued)

Scientific Name	Common Name	Distribution
Rubus hispidus	Trailing Dewberry	ME MA-W RI NY NJ DE MD
Rubus sp.	Bramble	NJ DE MD VA
Salix discolor	Pussy Willow	MA
Sambucus canadensis	Elder	MA-CC MA-W CT NY NJ DE MD VA NC
Schrankia uncinata	Sensitive Brier	FL-E
Serenoa repens	Saw Palmetto	FL-E
Smilax glauca	Sawbrier	MA-CC NJ DE VA NC SC FL-E FL-W
Smilax hispida	Greenbrier	FL-E
Smilax laurifolia	Laurel-leaved Greenbrier	NJ DE MD VA NC SC FL-E FL-W
Smilax pseudochina	China-brier	NJ
Smilax rotundifolia	Greenbrier	MA-CC MA-W NY NJ CT MD DE VA NC SC
Smilax sp.	Greenbrier	FL-E
Smilax walteri	Walter's Greenbrier	NJ MD DE VA NC
Spiraea latifolia	Meadow-sweet	ME MA-CC MA-W CT NJ
Spiraea tomentosa	Hardhack	MA CT MD
Styrax americana	Storax	SC FL-W MS
Symplocos tinctoria	Horse-sugar	MD NC FL-W
Taxus floridana	Yew	FL-W
Toxicodendron radicans	Poison Ivy	MA-CC MA-W RI CT NJ NY MD DE VA NC SC FL-E FL-W
Toxicodendron vernix	Poison Sumac	ME MA-CC MA-W RI CT NY NJ DE MD SC FL-E FL-W
Vaccinium angustifolium	Lowbush Blueberry	NH
Vaccinium arboreum	Farkleberry	MS
Vaccinium australe	Blueberry	SC
Vaccinium caesariense	Highbush Blueberry	NJ
Vaccinium corymbosum	Highbush Blueberry	ME NH MA RI CT NY NJ DE MD VA NC SC GA FL-E FL-W
Vaccinium elliottii	Elliott's Blueberry	FL-W MS
Vaccinium macrocarpon	American Cranberry	ME NH MA-CC MA-W RI CT NJ MD
Vaccinium oxycoccos	Small Cranberry	ME MA-CC MA-W RI NJ
Vaccinium pallidum	Blueberry	NJ
Vaccinium sempervirens	Blueberry	SC
Vaccinium sp.	Blueberry	ME DE MD VA
Vaccinium stamineum	Deerberry	CT
Vaccinium vacillans	Low Blueberry	NJ
Viburnum cassinoides	Witherod	ME MA-CC MA-W NY NJ GA
Viburnum dentatum	Southern Arrow-wood	NY NJ MD DE VA
Viburnum lentago	Sweet Viburnum	CT
Viburnum nudum	Possum-haw	NJ DE MD VA NC GA
Viburnum obovatum	Walter's Viburnum	FL-E
Viburnum recognitum	Arrow-wood	MA-CC MA-W CT
Viburnum sp.	Arrow-wood	CT SC FL
Vitis aestivalis	Summer Grape	NY MD
Vitis labrusca	Fox Grape	VA NC
Vitis riparia	River-bank Grape	NH CT
Vitis rotundifolia	Muscadine Grape	VA NC MD SC FL-E FL-W
Vitis sp.	Grape	DE FL-W
Zenobia pulverulenta	Zenobia	NC

APPENDIX A. Flora: Shrubs (Continued)

Synonym	see: Accepted Name
Amelanchier oblongifolia	see: *Amelanchier canadensis*
Ampelothamnus phyllyreifolius	see: *Pieris phyllyreifolia*
Amphicarpa bracteata	see: *Armphicarpaea bracteata*
Andromeda ligustrina	see: *Lyonia ligustrina*
Anisostichus capreolata	see: *Bignonia capreolata*
Apios tuberosa	see: *Apios americana*
Aronia atropurpurea	see: *Aronia prunifolia*
Arsenococcus ligustrinus	see: *Lyonia ligustrina*
Azalea viscosa	see: *Rhododendron viscosum*
Benzoin aestivale	see: *Lindera benzoin*
Cassandra calyculata	see: *Chamaedaphne calyculata*
Comptonia	see: *Myrica*
Cornus obliqua	see: *Cornus amomum* s. *obliqua*
Cornus stricta	see: *Cornus foemina*
Cuscuta	see: HERBS
Decodon verticillatus	see: HERBS
Dioscorea	see: HERBS
Eubotrys racemosa	see: *Leucothoe racemosa*
Gaylussacia dumosa v. *bigeloviana*	see: *Gaylussacia dumosa*
Gaylussacia dumosa v. *hirtella*	see: *Gaylussacia dumosa*
Ilex lucida	see: *Ilex coriacea*
Lonicera chinensis	see: *Lonicera japonica*
Myrica carolinensis	see: *Myrica pensylvanica*
Phoradendron serotinum	see: *Phoradendron flavescens*
Pieris nitida	see: *Lyonia lucida*
Pyrus arbutifolia	see: *Aronia arbutifolia*
Pyrus floribunda	see: *Aronia prunifolia*
Pyrus melanocarpa	see: *Aronia melanocarpa*
Rhododendron nudiflorum	see: *Rhododendron periclymenoides*
Rhododendron rhodora	see: *Rhododendron canadense*
Rhododendron viscosum v. *serrulatum*	see: *Rhododendron serrulatum*
Rhus radicans	see: *Toxicodendron radicans*
Rhus vernix	see: *Toxicodendron vernix*
Rosa virginiana	see: *Rosa palustris*
Smilax herbacea	see: HERBS
Sorbus	see: *Aronia*
Vaccinium atlanticum	see: *Vaccinium corymbosum*
Vaccinium atrococcum	see: *Vaccinium corymbosum*
Vaccinium fuscatum	see: *Vaccinium corymbosum*
Vaccinium oxycoccus	see: *Vaccinium oxycoccos*
Xolisma foliosiflora	see: *Lyonia ligustrina*
Zenobia cassinefolia	see: *Zenobia pulverulenta*

HERBS

Scientific Name	Common Name	Distribution
Acalypha rhomboidea	Three-seeded Mercury	VA NC
Acorus calamus	Sweet Flag	DE MD
Agalinis linifolia	Agalinis	FL-W
Agalinis purpurea	Agalinis	MD FL-W
Aletris lutea	Colic-root	FL-E FL-W
Allium sp.	Onion	SC

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Allium vineale	Field Garlic	NJ
Amaranthus cannabinus	Tidemarsh Waterhemp	DE
Andropogon glomeratus	Broomsedge	NJ MD FL-W
Andropogon sp.	Broomsedge	DE
Andropogon ternarius	Broomsedge	FL-W
Andropogon virginicus	Broomsedge	VA NC SC FL-W
Anemone quinquefolia	Wood Anemone	MA-CC
Apteria aphylla	Nodding Nixie	FL-E
Aralia nudicaulis	Wild Sarsparilla	ME NH MA-CC MA-W CT NJ NY
Arethusa bulbosa	Arethusa	ME MA-CC MA-W NJ DE VA
Arisaema triphyllum	Jack-in-the-pulpit	CT NY NJ MD
Arisaema triphyllum s. *pusillum*	Jack-in-the-pulpit	FL-E
Arisaema triphyllum s. *stewardsonii*	Jack-in-the-pulpit	MA-W
Aristida stricta	Wiregrass	FL-W
Aristida virgata	Arrowfeather Grass	FL-W
Aristolochia serpentaria	Virgina Snakeroot	FL-E
Arundinaria gigantea	Cane	NC SC FL-E MS
Asclepias incarnata	Swamp Milkweed	DE MD
Asclepias rubra	Milkweed	NJ
Asclepias syriaca	Milkweed	NJ
Asplenium platyneuron	Ebony Spleenwort	SC
Aster acuminatus	Whorled Wood Aster	ME MA-W
Aster carolinianus	Climbing Aster	FL-E
Aster chapmanii	Aster	FL-W
Aster dumosus	Aster	MD
Aster lateriflorus v. *pendulus*	Aster	NJ
Aster nemoralis	Bog Aster	MA-W NJ
Aster novae-angliae	New England Aster	RI CT
Aster novi-belgii	Aster	MA-CC MA-W NJ MD SC
Aster simplex	Aster	NJ
Aster sp.	Aster	DE MD VA
Bacopa caroliniana	Lemon Bacopa	SC
Balduina uniflora	Baldwinia	FL-W
Bartonia paniculata	Slender Bartonia	MA-W NJ MD SC FL
Bidens discoidea	Bur-marigold	DE
Bidens mitis	Bur-marigold	MD FL-E
Bidens sp.	Beggars-ticks	MA-CC MA-W
Bidens tripartita	Beggars-ticks	NJ
Bigelowia nudata	Rayless Goldenrod	FL-W
Boehmeria cylindrica	False Nettle	NJ MD DE FL-E
Botrychium sp.	Grapefern	MD
Brasenia schreberi	Water-shield	DE SC
Burmannia biflora	Northern Bumannia	SC
Burmannia capitata	Southern Bumannia	SC
Cacalia diversifolia	Indian Plantain	FL-E
Calamagrostis canadensis	Reed Bentgrass	NJ
Calamagrostis cinnoides	Reed Bentgrass	MD
Calla palustris	Wild Calla	MA-W RI CT NJ
Calopogon pallidus	Grass-pink	FL-W
Calopogon sp.	Grass-pink	NJ
Calopogon tuberosus	Grass-pink	MA-CC MA-W RI CT NJ
Campanula aparinoides	Marsh Bellflower	NJ
Cardamine bulbosa	Spring Cress	FL-E

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Carex alata	Sedge	NC VA
Carex atlantica	Sedge	NJ
Carex bullata	Sedge	NJ
Carex canescens	Sedge	MA-CC MA-W
Carex chapmanii	Sedge	FL-E
Carex collinsii	Sedge	RI NY NJ DE MD SC
Carex comosa	Sedge	DE
Carex crinita	Sedge	MD
Carex echinata	Sedge	MA-CC NJ
Carex emoryi	Sedge	NJ
Carex howei	Sedge	MA-CC MA-W NY NJ
Carex intumescens	Sedge	MA-W MD
Carex joorii	Sedge	FL-W
Carex lasiocarpa	Hairy-fruited Sedge	ME RI CT
Carex leptalea	Sedge	MA-W FL-E
Carex littoralis	Sedge	NJ
Carex lonchocarpa	Long Sedge	MA-W CT NY NJ DE MD
Carex lurida	Sedge	MA-W
Carex rostrata	Beaked Sedge	RI CT
Carex smalliana	Sedge	MA-W
Carex spp.	Sedge	RI NJ MD DE VA SC
Carex stricta	Sedge	MA-W CT NJ
Carex trisperma	Three-seeded Sedge	MA-CC MA-W RI CT NJ
Carex walterana	Sedge	NJ
Carphephorus pseudoliatris	Carphephorus	FL-W
Chamaelirium luteum	Fairy-wand	FL-E
Chasmanthium ornithorhynchum	Grass	FL-E
Chelone glabra	White Turtlehead	DE
Chimaphila maculata	Spotted Wintergreen	CT DE
Chrysoma pauciflosculosa	Few-rayed Goldenrod	SC
Chrysosplenium americanum	Golden Saxifrage	MA-W
Cicuta bulbifera	Water Hemlock	RI
Cicuta sp.	Water Hemlock	DE
Cinna arundinacea	Wood Reedgrass	MA-W MD
Circaea alpina	Enchanter's Nightshade	MA-CC MA-W
Cirsium aff. *muticum*	Thistle	FL-E
Cladium jamaicense	Saw-grass	FL-E
Cladium mariscoides	Twig Rush	RI MD
Cleistes divaricata	Orchid	NJ
Clintonia borealis	Clintonia	NH
Clintonia umbellulata	Speckled Wood Lily	MA-CC
Commelina sp.	Dayflower	MD
Coptis trifolia	Goldthread	ME NH MA-W CT NJ
Corallorrhiza innata	Coral-root	MA-W
Corallorrhiza trifida	Coral-root	MA-W
Coreopsis aff. *leavenworthii*	Coreopsis	FL-W
Cornus canadensis	Dwarf Cornel	ME NH MA-W RI NJ
Ctenium aromaticum	Toothache Grass	FL-W
Cuscuta cephalanthi	Dodder	NJ
Cuscuta compacta	Dodder	NJ MD FL-W
Cuscuta gronovii	Dodder	DE MD
Cuscuta pentagona	Dodder	DE
Cuscuta sp.	Dodder	CT DE MD

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Cyperus flavescens	Sedge	MD
Cypripedium acaule	Pink Lady's-slipper	NH MA-W CT DE SC
Cypripedium sp.	Lady's-slipper	CT
Decodon verticillatus	Swamp Looestrife	ME MA-CC MA-W RI CT NJ DE MD
Dennstaedtia punctilobula	Hay-scented Fern	CT
Dichanthelium acuminatum	Panic-grass	FL-W
Dichanthelium dichotomum v. ensifolium	Panic-grass	MD
Dichanthelium sabulorum	Hemlock Panicum	MD
Dichromena latifolia	Sedge	FL-W
Dioscorea hirticaulis	Yam	NJ
Dioscorea sp.	Wild Yam	MD
Dioscorea villosa	Wild Yam	NJ MD
Dioscorea villosa v. floridana	Wild Yam	FL-E
Drosera capillaris	Pink Sundew	SC
Drosera filiformis	Sundew	NJ FL-W
Drosera intermedia	Water Sundew	ME MA-CC MA-W CT NJ MD DE SC
Drosera longifolia	Sundew	NJ
Drosera rotundifolia	Round-leaved Sundew	ME NH MA-CC MA-W RI CT NJ DE MD SC
Dryopteris cristata	Crested Wood Fern	MA-W CT NJ
Dryopteris ludoviciana	Florida Shield Fern	FL-E
Dryopteris spinulosa	Spinulose Wood Fern	MA-CC NJ
Dulichium arundinaceum	Three-way Sedge	MA-W CT NJ DE MD SC
Eclipta alba	Eclipta	NJ
Eleocharis equisitoides	Northern Jointed Spikerush	MD
Eleocharis olivacea	Spikerush	ME MD DE
Eleocharis quadrangulata	Spikerush	DE
Eleocharis robbinsii	Spikerush	NJ SC
Eleocharis smallii	Small's Spikerush	ME
Eleocharis sp.	Spikerush	NJ DE MD
Eleocharis tuberculosa	Spikerush	CT NJ
Epidendrum conopseum	Green-fly Orchid	FL-E
Erechtites hieraciifolia	Fireweed	MD
Erianthus giganteus	Sugarcane Plumegrass	MD SC
Eriocaulon compressum	Pipewort	NJ DE MD VA SC
Eriocaulon decangulare	Pipewort	NJ FL-W
Eriocaulon parkeri	Pipewort	DE MD
Eriocaulon septangulare	Seven-angled Pipewort	ME MD
Eriocaulon sp.	Pipewort	MD SC
Eriophorum sp.	Cotton-grass	RI NJ
Eriophorum spissum	Hare's-tail	MA-W
Eriophorum tenellum	Cotton-grass	MA-CC MA-W NJ CT
Eriophorum virginicum	Cotton-grass	ME MA-CC MA-W CT NJ MD
Eryngium integrifolium	Blue-flowered Eryngo	SC
Eupatoriadelphus dubius	Coastal Plain Joepyeweed	DE
Eupatoriadelphus fistulosus	Joepyeweed	FL-E
Eupatoriadelphus purpureus	Joepyeweed	CT MD
Eupatorium capillifolium	Dogfennel Joepyeweed	MD
Eupatorium leucolepis	Boneset	NJ
Eupatorium perfoliatum	Boneset	NJ MD
Eupatorium pilosum	Boneset	NJ MD
Eupatorium recurvans	Boneset	FL-W
Eupatorium resinosum	Boneset	NJ

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Eupatorium rotundifolium	Boneset	MD
Eupatorium semiserratum	Boneset	FL-W
Eupatorium sp.	Boneset	DE
Euphorbia maculata	Eyebane	VA NC
Euthamia galetorum	Flat-topped Goldenrod	NJ MD
Euthamia minor	Flat-topped Goldenrod	FL-W
Fimbristylis autumnalis	Slender fimbristylis	MD
Fimbristylis castanea	Sedge	FL-E
Fragaria virginiana	Wild Strawberry	NJ
Fuirena sp.	Umbrella-grass	DE
Fuirena squarrosa	Umbrella-grass	DE MD SC FL-W
Galium palustre	Bedstraw	CT
Galium sp.	Bedstraw	DE
Galium tinctorium	Clayton's Bedstraw	MA-W MD
Gentiana saponaria	Soapwort	MD
Glyceria obtusa	Mannagrass	MA-W RI CT NY DE MD
Glyceria striata	Fowl-meadow Grass	MA-CC MA-W
Goodyera pubescens	Rattlesnake plantain	NC
Gratiola aurea	Golden Hedge-hyssop	MD
Habenaria strictissima v. odontopetala	Orchid	FL-E
Helenium autumnale	Sneezeweed	MD
Helianthus floridanus	Sunflower	FL-W
Helonias bullata	Swamp Pink	NJ DE VA
Hepaticae spp.	Liverworts	NH RI NJ
Hibiscus moscheutos	Swamp Rose	MD
Hudsonia ericoides	Heather	SC
Hydrocotyle sp.	Water Pennywort	MD
Hydrocotyle umbellata	Marsh Pennywort	FL-E
Hymenocallis sp.	Spider-lily	FL-E
Hypericum canadense	Canada St. Johnswort	MD SC
Hypericum denticulatum	St. Johnswort	NJ
Hypericum gentianoides	Pineweed	CT DE
Hypericum mutilum	Dwarf St. Johnswort	MD SC
Hypericum spp.	St. Johnswort	DE SC
Hypoxis hirsuta	Yellow-eyed-grass	FL-W
Hypoxis leptocarpa	Yellow-eyed-grass	FL-E
Impatiens capensis	Spotted Touch-me-not	MA-W NJ DE MD
Impatiens sp.	Touch-me-not	MA-W
Iris prismatica	Slender Blue Flag	CT NJ DE MD
Iris sp.	Flag	DE MD VA
Iris versicolor	Blue Flag	MA-W CT NJ DE MD
Isoetes flaccida	Florida Quillwort	FL-E
Juncus abortivus	Bog Rush	MD
Juncus caesariensis	Rush	NJ
Juncus canadensis	Canada Rush	CT NJ MD
Juncus effusus	Soft Rush	DE MD
Juncus marginatus	Shore Rush	FL-W
Juncus militaris	Rush	NJ
Juncus pelocarpus	Rush	ME RI
Juncus polycephalus	Many-headed Rush	FL-W
Juncus sp.	Rush	MA-W DE MD SC
Justicia crassifolia	Water-willow	FL-W
Lachnanthes caroliniana	Redroot	FL-W
Lachnocaulon anceps	Hairy Pipewort	SC FL-W

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Lactuca canadensis	*Wild Lettuce*	*NJ*
Leersia oryzoides	*Rice Cutgrass*	*MA-W RI MD*
Leersia sp.	*Cutgrass*	*DE*
Leersia virginica	*Virginia Cutgrass*	*FL-E*
Lemna sp.	*Duckweed*	*DE*
Liatris spicata	*Blazing-star*	*FL-W*
Lilium canadense	*Canada Lily*	*MA-W NY NJ*
Lilium catesbaei	*Pine Lily*	*FL-W*
Linum virginianum	*Woodland Flax*	*DE*
Listera australis	*Twayblade*	*NJ*
Listera convallarioides	*Broad-lipped Twayblade*	*NJ*
Listera cordata	*Heartleaf Twayblade*	*MA-CC MA-W RI*
Lobelia amoena v. glandulifera	*Lobelia*	*FL-E*
Lobelia canbyi	*Lobelia*	*NJ*
Lobelia cardinalis	*Cardinal-flower*	*MD*
Lobelia floridana	*Lobelia*	*FL-W*
Lobelia nuttallii	*Lobelia*	*NJ*
Lobelia puberula	*Downy Lobelia*	*SC*
Lobelia sp.	*Lobelia*	*DE SC*
Lophiola americana	*Lophiola*	*NJ FL-W*
Ludwigia alternifolia	*Seedbox*	*MD VA NC*
Ludwigia linearis	*False Loostrife*	*FL-W*
Ludwigia palustris	*False Loosetrife*	*FL-E*
Ludwigia pilosa	*False Loostrife*	*FL-W*
Ludwigia sphaerocarpa	*Globe-fruited Ludwigia*	*MD*
Lycopodium alopecuroides	*Foxtail Clubmoss*	*NJ FL-W*
Lycopodium appressum	*Southern Clubmoss*	*NJ DE MD SC*
Lycopodium carolinianum	*Carolina Clubmoss*	*NJ SC FL-W*
Lycopodium clavatum	*Running Clubmoss*	*CT*
Lycopodium complanatum	*Running Groundpine*	*CT*
Lycopodium copelandii	*Clubmoss*	*NJ*
Lycopodium inundatum	*Bog Clubmoss*	*MA-CC MA-W RI CT*
Lycopodium lucidulum	*Shining Clubmoss*	*MA-CC MA-W CT NY*
Lycopodium obscurum	*Tree Clubmoss*	*MA-W CT SC*
Lycopus amplectens	*Bugleweed*	*NJ*
Lycopus cokeri	*Bugleweed*	*SC*
Lycopus rubellus	*Stalked Water Hoarhound*	*MD*
Lycopus sp.	*Bugleweed*	*RI MD DE VA*
Lycopus uniflorus	*Bugleweed*	*ME MA-W CT MD*
Lycopus virginicus	*Bugleweed*	*NJ*
Lysimachia sp.	*Loosestrife*	*ME RI*
Lysimachia terrestris	*Earth Loosestrife*	*ME MD*
Maianthemum canadense	*False Lily-of-the-valley*	*ME NH MA-CC MA-W RI CT NY NJ*
Malaxis spicata	*Adder's-mouth Orchid*	*FL-E*
Mayaca fluviatilis	*Bog-moss*	*SC*
Medeola virginiana	*Indian Cucumber-root*	*MA-CC MA-W CT*
Menyanthes trifoliata	*Bogbean*	*RI*
Mitchella repens	*Partridge Berry*	*MA-CC MA-W CT NY NJ DE MD VA NC FL-W*
Monotropa uniflora	*Indian Pipe*	*MA-W CT NJ MD*
Muhlenbergia uniflora	*Drop-seed-grass*	*NJ*
Myriophyllum humile	*Low Watermilfoil*	*MD*
Narthecium americanum	*Asphodel*	*NJ*

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Nasturtium microphyllum	*Watercress*	*FL-E*
Nasturtium officinale	*Watercress*	*DE*
Nuphar luteum s. macrophyllum	*Spatter-dock*	*DE MD VA*
Nuphar luteum s. variegatum	*Spatter-dock*	*ME NJ*
Nuphar sp.	*Spatter-dock*	*CT*
Pontederia cordata	Pickerelweed	CT DE MD FL-E
Ponthieva racemosa	Shadow-witch Orchid	FL-E
Potamogeton confervoides	Pondweed	ME NJ
Potamogeton sp.	Pondweed	CT DE
Proserpinaca palustris	Mermaid-weed	CT MD
Proserpinaca pectinata	Mermaid-weed	MD SC FL-W
Proserpinaca sp.	Mermaid-weed	SC
Psilocarya nitens	Short-leaved Baldrush	MD
Pteridium aquilinum	Brackenfern	CT NJ DE SC FL-E
Rhexia alifanus	Meadow-beauty	FL-W
Rhexia mariana	Meadow-beauty	DE MD
Rhexia virginica	Meadow-beauty	CT NJ DE MD
Rhynchospora alba	Whitebeaked-rush	ME MA-W NJ DE MD VA SC
Rhynchospora baldwinii	Baldwin's Beaked-rush	FL-W
Rhynchospora capitellata	Beaked-rush	NJ
Rhynchospora cephalantha	Capitate Beaked-rush	NJ FL-W
Rhynchospora chalarocephala	Looseheaded Beaked-rush	NJ
Rhynchospora chapmanii	Chapman's Beaked-rush	FL-W
Rhynchospora corniculata	Horned Beaked-rush	FL-W
Rhynchospora filifolia	Bristle-leaved Beaked-rush	FL-W
Rhynchospora fusca	Brown Beaked-rush	NJ
Rhynchospora glomerata	Clustered Beaked-rush	MD
Rhynchospora gracilenta	Slender Beaked-rush	MD FL-W
Rhynchospora inundata	Innundated Beaked-rush	FL-E
Rhynchospora knieskernii	Beaked-rush	NJ SC
Rhynchospora macrostachya	Horned-rush	DE MD
Rhynchospora microcephala	Capitate Beaked-rush	NJ
Rhynchospora miliacea	Millet Beaked-rush	FL-E
Rhynchospora oligantha	Few-flowered Beaked-rush	NJ
Rhynchospora plumosa	Plumed Beaked-rush	FL-W
Rhynchospora rariflora	Thread Beaked-rush	FL-W
Rhynchospora spp.	Beaked-rush	SC
Rhynchospora torreyana	Torrey's Beaked-rush	NJ
Ruellia caroliniensis	Wild Petunia	FL-E
Sabatia difformis	Sabatia	NJ
Sabatia quadrangula	Sabatia	FL-W
Sagittaria engelmanniana	Arrowhead	NJ
Sagittaria graminea	Water-plantain	FL-W
Sagittaria lancifolia	Lance-leaved Arrowhead	FL-E
Sagittaria latifolia	Arrowhead	MA-W RI CT NJ MD
Sagittaria sp.	Water-plantain	NJ
Sagittaria subulata	Awlleaf Arrowhead	MD
Samolus parviflorus	Pineland Pimpernel	FL-E
Sarracenia flava	Pitcherplant	SC FL-W
Sarracenia flava x S. purpurea	Pitcherplant	SC
Sarracenia psittacina	Pitcherplant	FL-W
Sarracenia purpurea	Pitcherplant	ME MA-W RI CT NJ DE MD SC
Sarracenia purpurea v. venosa	Pitcherplant	DE

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Sarracenia rubra	Pitcherplant	SC
Saururus cernuus	Lizards-tail	DE MD VA NC FL-E
Schizaea pusilla	Curly-grass	NJ
Scirpus americanus	Olney's Bulrush	MD
Scirpus cyperinus	Bulrush	MA-CC NJ MD DE VA FL-W
Scirpus etuberculatus	Bulrush	SC
Scirpus etuberculatus x S. subterminalis	Bulrush	SC
Scirpus subterminalis	Swaying Rush	ME NJ SC
Scleria baldwinii	Nut-rush	FL-W
Scleria reticularis	Nut-rush	FL-W
Sclerolepis uniflora	Sclerolepis	NJ MD
Scutellaria lateriflora	Mad-dog Scutellaria	DE MD
Selaginella apoda	Spikemoss	DE MD FL-E
Senecio sp.	Ragwort	DE
Smilacina racemosa	False Solomon's-seal	NY
Smilacina trifolia	False Solomon's-seal	NJ
Smilax herbacea	Carrion Flower	MD
Solanum dulcamara	False Bittersweet	NJ
Solidago nemoralis	Goldenrod	MD
Solidago nuttallii	Goldenrod	NJ
Solidago patula	Roughleaf Goldenrod	SC
Solidago rugosa	Goldenrod	NJ MD
Solidago sempervirens	Goldenrod	FL-E
Solidago spp.	Goldenrod	CT DE MD
Solidago stricta	Goldenrod	NJ
Solidago uliginosa	Swamp Goldenrod	MA-W MD
Solidago verna	Goldenrod	SC
Sparganium androcladum	Burreed	NJ
Sparganium eurycarpum	Burreed	DE
Sparganium sp.	Burreed	CT DE
Spiranthes cernua	Ladies-tresses	DE
Spiranthes praecox	Ladies-tresses	NJ
Symplocarpus foetidus	Skunk-cabbage	ME NH MA-W CT NY NJ
Syngonanthus flavidulus	Pipewort	FL-W
Taraxacum officinale	Dandelion	NJ
Thalictrum sp.	Meadow-rue	DE MD VA
Thelypteris noveboracensis	New York Fern	CT NJ
Thelypteris thelypteroides	Marsh Fern	ME MA-CC MA-W RI CT NJ DE MD FL-E
Thelypteris simulata	Massachusetts Fern	MA-CC MA-W RI CT NY NJ DE MD VA
Tillandsia bartramii	Bartram's Wild-pine	FL-E
Tillandsia usneoides	Spanish-moss	FL-E
Tipularia discolor	Cranefly Orchid	DE MD NC
Tofieldia racemosa	False Asphodel	NJ SC
Triadenum virginicum	Marsh St. Johnswort	MA-W RI CT NY NJ DE MD
Triadenum sp.	St. Johnswort	MD
Trientalis borealis	Star-flower	NH MA-CC MA-W RI NY NJ
Trillium undulatum	Painted Trillium	MA-W
Trisetum pensylvanicum	Swamp Oats	MA-CC MA-W
Typha angustifolia	Cattail	MD DE
Typha latifolia	Common Cattail	MA-W DE MD
Utricularia biflora	Bladderwort	NJ
Utricularia cornuta	Bladderwort	ME RI NJ SC FL-W

APPENDIX A. Flora: Herbs (Continued)

Scientific Name	Common Name	Distribution
Utricularia fibrosa	Bladderwort	NJ MD
Utricularia geminiscapa	Bladderwort	ME NJ
Utricularia gibba	Bladderwort	DE MD
Utricularia juncea	Bladderwort	NJ DE MD SC FL-W
Utricularia macrorhiza	Bladderwort	DE MD
Utricularia minor	Bladderwort	ME
Utricularia purpurea	Purple Bladderwort	NJ MD
Utricularia resupinata	Bladderwort	NJ
Utricularia spp.	Bladderwort	ME MA-CC NJ MD
Utricularia subulata	Bladderwort	NJ
Uvularia sessilifolia	Bellwort	NJ
Vernonia noveboracensis	New York Ironweed	MD
Viola blanda	White Violet	MA-CC
Viola cucullata	Marsh Violet	MA-CC MA-W
Viola floridana	Florida Violet	FL-E
Viola incognita	White Violet	MA-CC
Viola lanceolata	White Violet	NJ DE
Viola pallens	White Violet	MA-W NY
Viola papilionacea	Marsh Violet	NY
Viola primulifolia	Primrose-leaved Violet	MA-W
Viola sp.	Violet	ME CT NJ DE MD
Vittaria lineata	Shoestring Fern	FL-E
Woodwardia areolata	Netted Chain Fern	MA-CC MA-W CT NY NJ DE MD SC FL-E FL-W
Woodwardia virginica	Virginia Chain Fern	ME MA-CC MA-W CT NY NJ MD DE NC FL-W
Xerophyllum asphodeloides	Xerophyllum	NJ
Xyris ambigua	Yellow-eyed-grass	FL-W
Xyris baldwiniana	Yellow-eyed-grass	FL-W
Xyris caroliniana	Yellow-eyed-grass	CT NJ MD
Xyris difformis	Common Xyris	ME
Xyris elliottii	Yellow-eyed-grass	FL-W
Xyris fimbriata	Yellow-eyed-grass	NJ
Xyris montana	Yellow-eyed -grass	ME
Xyris smalliana	Yellow-eyed-grass	NJ
Xyris sp.	Yellow-eyed-grass	DE SC
Xyris stricta	Yellow-eyed-grass	FL-W
Xyris torta	Yellow-eyed-grass	CT NJ
Zigadenus glaberrimus	Zigadenus	FL-W
Zizania aquatica	Wild Rice	MD VA

Synonym	see: Accepted Name
Acnida cannabina	see: *Amaranthus cannabinus*
Andropogon virginicus v. *abbreviatus*	see: *Andropogon glomeratus*
Arisaema acuminatum	see: *Arisaema triphyllum* s. *pusillum*
Arnoglossum diversifolium	see: *Cacalia diversifolia*
Arundinaria tecta	see: *Arundinaria gigantea*
Asclepias incarnatus s. *pulchra*	see: *Asclepias incarnata*
Aspidium thelypteris	see: *Thelypteris thelypteroides*
Aster novi-belgii v. *laevigatus*	see: *Aster novi-belgii*
Calopogon pulchellus	see: *Calopogon tuberosus*
Carex cephalantha	see: *Carex echinata*

APPENDIX A. Flora: Herbs (Continued)

Synonym	see: Common Name
Carex filiformis	see: *Carex lasiocarpa*
Carex incomperta	see: *Carex atlantica*
Carex lasiocarpa v. *americana*	see: *Carex lasiocarpa*
Carex stellulata	see: *Carex echinata*
Carex stricta v. *strictior*	see: *Carex stricta*
Carex subulata	see: *Carex collinsii*
Carex trisperma v. *billingsii*	see: *Carex trisperma*
Carex walterana v. *brevis*	see: *Carex walterana*
Castalia odorata	see: *Nymphaea odorata*
Chondrophora nudata	see: *Bigelowia nudata*
Coptis groenlandica	see: *Coptis trifolia*
Dioscorea floridana	see: *Dioscorea villosa* v. *floridana*
Dioscorea quaternata	see: *Dioscorea villosa*
Dryopteris palustris	see: *Thelypteris thelypteroides*
Dryopteris simulata	see: *Thelypteris simulata*
Eupatorium dubium	see: *Eupatoriadelphus dubius*
Eupatorium fistulosum	see: *Eupatoriadelphus fistulosus*
Eupatorium purpureum	see: *Eupatoriadelphus purpureus*
Eupatorium rotundifolium v.*saundersii*	see: *Eupatorium pilosum*
Eupatorium verbenifolium	see: *Eupatorium pilosum*
Fuirena hispida	see: *Fuirena squarrosa*
Gaultheria hispidula	see: SHRUBS
Gaultheria procumbens	see: SHRUBS
Habenaria	see: *Platanthera*
Hibiscus palustris	see: *Hibiscus moscheutos*
Hypericum brachyphyllum	see: Shrubs
Hypericum densiflorum	see: Shrubs
Hypericum fasciculatum	see: Shrubs
Hypericum virginicum	see: *Triadenum virginicum*
Impatiens fulva	see: *Impatiens capensis*
Juncus pelocarpus v. *crassicaudex*	see: *Juncus abortivus*
Lilium canadense s. *michiganense*	see: *Lilium canadense*
Lilium superbum	see: *Lilium canadense*
Lobelia glandulifera	see: *Lobelia amoena* v. *glandulifera*
Lophiola aurea	see: *Lophiola americana*
Lorinseria areolata	see: *Woodwardia areolata*
Lycopodium adpressum	see: *Lycopodium appressum*
Lycopodium selago v. *appressum*	see: *Lycopodium appressum*
Mayaca aubletii	see: *Mayaca fluviatilis*
Nuphar advena	see: *Nuphar luteum* s. *macrophyllum*
Oplismenus setarius	see: *Oplismenus hirtellus*
Osmunda regalis v. *spectabilis*	see: *Osmundia regalis*
Panicularia obtusa	see: *Glyceria obtusa*
Panicum ensifolium	see: *Dichanthelium dichotomum* v. *ensifolium*
Parnassia grandiflora	see: *Parnassia grandifolia*
Peltandra glauca	see: *Peltandra sagittifolia*
Peltandra luteospadix	see: *Peltandra virginica*
Sabatia lanceolata	see: *Sabatia difformis*
Sagittaria longirostra	see: *Sagittaria latifolia*
Scirpus rubricosus	see: *Scirpus cyperinus*
Selaginella apus	see: *Selaginella apoda*
Smilacina trifoliata	see: *Smilacina trifolia*
Solidago rumifolia	see: *Solidago rugosa*

APPENDIX A. Flora: Herbs (Concluded)

Synonym	see: Common Name
Solidago tenuifolia	see: *Euthamia galetorum*
Spathyema foetida	see: *Symplocarpus foetidus*
Taraxacum laevigatum	see: *Taraxacum officinale*
Thelypteris spinulosa	see: *Dryopteris spinulosa*
Thelypteris palustris	see: *Thelypteris thelypteroides*
Trientalis americana	see: *Trientalis borealis*
Unifolium	see: *Maianthemum*
Utricularia vulgaris	see: *Utricularia macrorhiza*
Vagnera racemosa	see: *Smilacina racemosa*
Viola incognita v. *forbesii*	see: *Viola incognita*
Xerophyllum setifolium	see: *Xerophyllum asphodeloides*
Xyris congdonii	see: *Xyris smalliana*

APPENDIX B. FAUNA OF ATLANTIC WHITE CEDAR WETLANDS

Sites are listed from North to South. R = Rhode Island (R. Enser, pers. comm.); P = New Jersey Pinelands (NJPC 1980). Herptile species were selected for intensive study by the New Jersey Pinelands Commission (NJPC) due to their distribution patterns or because their populations are known to be declining (NJPC 1980). L = Delmarva Peninsula (Dill et al., unpubl.); G = Great Dismal Swamp (GDS), Virginia and North Carolina: Ge = extirpated in the region; G@ = of special concern in GDS (USFWS 1986b); D = Dare County, North Carolina (Braswell and Wiley 1982; Noffsinger et al. 1984; Peacock and Lynch 1982). Scientific names are as written in the source, or as implied by the common name if no scientific name is noted in the source.

Part 1. Mammals

Distribution R	P	L	G	D	Species
	P			D	Virginia opossum *Didelphus virginiana*
R					Masked shrew *Sorex cinereus*
				D	Southeastern shrew *Sorex longirostris*
				D	Dismal Swamp short-tailed shrew *Blarina telmalestes*
				D	Eastern mole *Scalopus aquaticus*
	P			D	Star-nosed mole *Condylura cristata*
	P				Little brown bat *Myotis lucifugus*
	P				Eastern pipistrelle *Pipistrellus subflavus*
	P				Big brown bat *Eptesicus fuscus*
				D	Red bat *Lasiurus borealis*
				D	Evening bat *Nycticeius humeralis*
				D	Marsh rabbit *Sylvilagus palustris*
	P		G		Eastern cottontail *Sylvilagus floridanus*
R					Snowshoe hare *Lepus americanus*
			G		Eastern chipmunk *Tamias striatus*
		L			Red squirrel *Tamiascurus hudsonicus*
			G	D	Gray squirrel *Sciurus carolinensis*
R					Southern flying squirrel *Glaucomys volans*
	P				Beaver *Castor canadensis*
				D	Marsh rice rat *Oryzomys palustris*
				D	Eastern harvest mouse *Reithrodontomys humulis*
			G	D	White-footed mouse *Peromyscus leucopus*
				D	Cotton mouse *Peromyscus gossypinus*
			G	D	Golden mouse *Ochrotomys nuttalli*
R					Woodland jumping mouse *Napeozapus insignia*
				D	Hispid cotton rat *Sigmodon hispidus*
R	P				Southern red-backed vole *Clethrionomys gapperi*
	P			D	Meadow vole *Microtus pennsylvanicus*
	P				Pine vole *Pitymys pinetorum*
	P			D	Muskrat *Odatra zibethicus*
	P		G		Southern bog lemming *Synaptomys cooperi*
	P				Meadow jumping mouse *Zapus hudsonius*
			Ge		Gray wolf *Canis lupus*
				D	Red fox *Vulpes vulpes*
			G	D	Gray fox *Urocyon cinereoargenteus*
		L	G@	D	Black bear *Ursus americanus*
R	P	L		D	Raccoon *Procyon lotor*
	P			D	Long-tailed weasel *Mustela frenata*
R	P	L			Mink *Mustela vison*
R	P	L		D	River otter *Lutra canadensis*
	P				Striped skunk *Mephitis mephitis*
			G	D	Bobcat *Felis rufus*
	P	L	G@	D	White-tailed deer *Odocoileus virginianus*

APPENDIX B. Fauna (Concluded)

Part 2. Herptiles

Distribution R	P	L	G	D	Species
			G	D	Five-lined skink *Eumeces inexpectatus*
				D	Ground skink *Scincella lateralis*
				D	Slimy salamander *Plethodon glutinosus*
R					Red-backed salamander *Plethodon cinereus*
R					Spotted salamander *Ambystoma maculatum*
	P				Four-toed salamander *Hemidactylium scutatum*
	P				Eastern mud salamander *Pseudotriton m. montanus*
	P				Northern red salamander *Pseudotriton r. ruber*
			G		Red-backed salamander *Plethodon cinereus*
R					American toad *Bufo americanus*
			G		Fowler's toad *Bufo woodhousei fowleri*
	P				Northern cricket frog *Acris c. crepitans*
R					Spring peeper *Hyla crucifer*
	P				Pine Barrens treefrog *Hyla andersoni*[a]
R					Gray tree frog *Hyla versicolor*
	P			D	Carpenter frog *Rana virgatipes*[a]
	P				Spotted turtle *Clemmys guttata*
	P				Bog turtle *Clemmys muhlenbergi*
R					Eastern painted turtle *Chrysemys picta*
	P				Red-bellied turtle *Chrysemys rubriventris*
		L			Northern water snake *Nerodia sipedon*
		L			Redbelly water snake *Nerodia erythrogaster*
	P				Northern red-bellied snake *Storeria o. occipitomaculata*[a]
R					Common garter snake *Thamnophis sirtalis*
	P				Northern black racer *Coluber c. constrictor*
	P				Northern pine snake *Pituophis m. melanoleucus*[a]
	P		G		Eastern king snake *Lampropeltis g. getulus*[b]
			G		Eastern hognose snake *Heterodon platyrhinos*
			G		Southern copperhead *Agkistrodon c. contortris*
	P				Timber rattlesnake *Crotalus horridus*
			G		Canebrake rattlesnake *Crotalus horridus atricaudatus*

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[a] species has limited distribution in New Jersey; occurs only in the Pinelands

[b] occurs chiefly in the Pinelands; also found in surrounding areas

APPENDIX C. Hydric Soils

Definition (USDA, SCS 1985a): A hydric soil is a soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

Criteria for hydric soils (soil orders, groups, and types are defined in USDA, SCS 1985a):

1. All Histosols except Folists, or
2. Soils in Aquic suborders, Aquic subgroups, Albolls suborder, Salorthids great group, or Pell great groups of Vertisols that are:
   a. somewhat poorly drained and have water table less than 0.5 ft from the surface at some time during the growing season, or
   b. poorly drained or very poorly drained and have either:
      i. water table at less than 1.0 ft from the surface at some time during the growing season if permeability is equal to or greater than 6.0 inches/hr in all layers within 20 inches, or
      ii. water table at less than 1.5 ft from the surface at some time during the growing season if permeability is less than 6.0 inches/hr in any layer within 20 inches, or
3. Soils that are ponded during any part of the growing season, or
4. Soils that are frequently flooded for long duration during the growing season.

pH modifiers (from Cowardin et al. 1979):

Modifier	pH of Water
Acid	<5.5
Circumneutral	5.5-7.4
Alkaline	7.4

APPENDIX D. Personal Communications and Acknowledgments: Reference

Sources of unpublished data and others whose contributions are noted throughout the Profile. NHP = Natural Heritage Program and Inventory; TNC = The Nature Conservancy; NWR = Natural Wildlife Refuge.

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Atlantic white cedar (*Chamaecyparis thyoides*) is geographically restricted to freshwater wetlands in a narrow band along the eastern coastal United States from Maine to Mississippi. The shallow, dark, generally acid peatland waters are low in nutrients and are buffered by complex organic acids. Distinctive biotic assemblages grow under conditions too extreme for the majority of temperate-dwelling organisms. In many regions, cedar wetlands are refugia for species that are rare, endangered, or threatened locally or nationally. After centuries of development, the landscape has been so changed that much of the tree's original habitat is destroyed. Major impacts include improper logging, draining, and substrate alteration for agriculture, and commercial construction. Stands can vigorously regenerate despite multiple incursions. With appropriate protection and aggressive management where necessary, Atlantic white cedar can also be reintroduced to many former cedar sites.

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